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AIR TRANSPORTABLE SHELTERS: ESTIMATING THE 1985 USAF REQUIREMEN--ETC(U)
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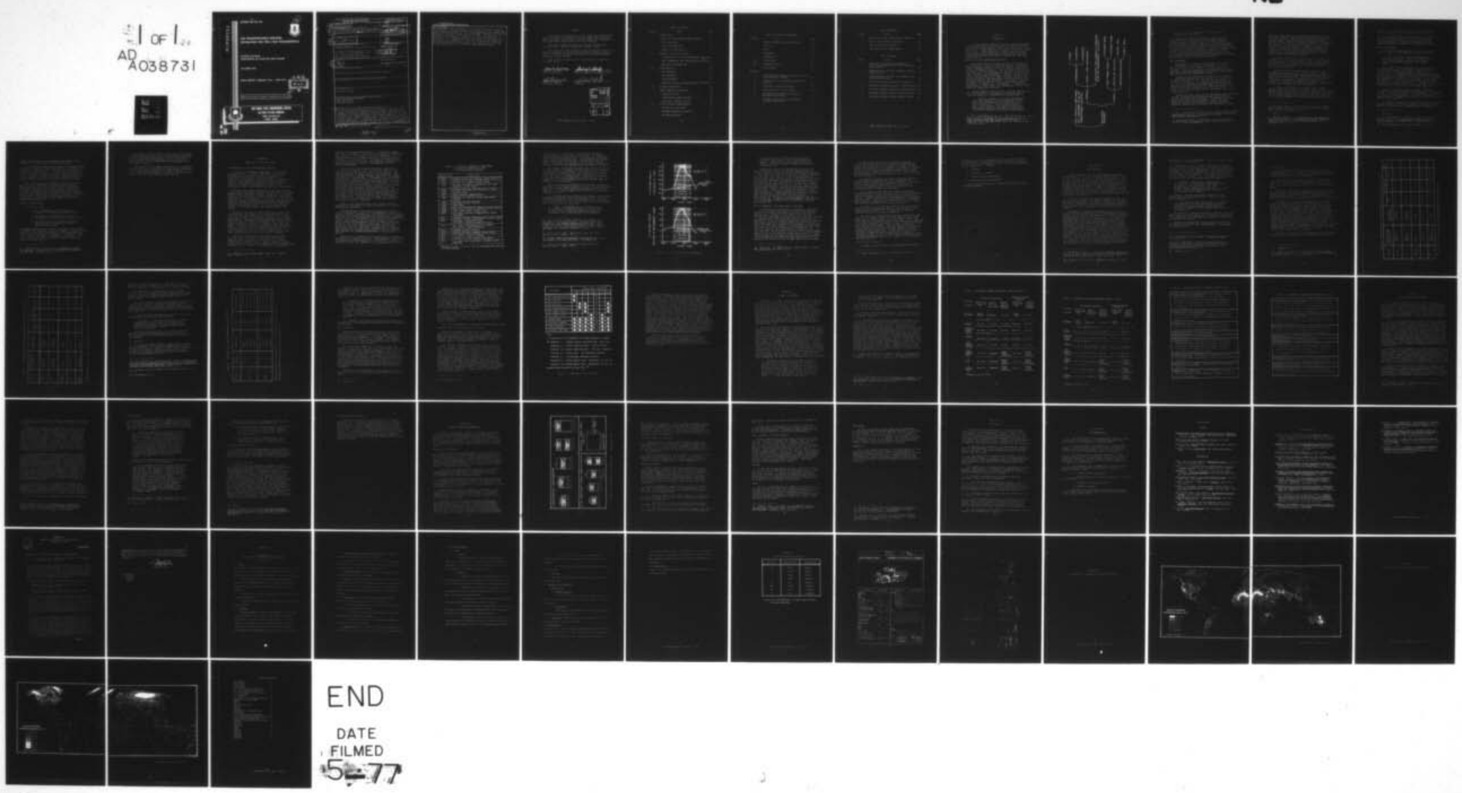

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AIR TRANSPORTABLE SHELTERS: ESTIMATING THE 1985 USAF REQUIREMENTS

SYSTEMS DIVISION
DIRECTORATE OF FACILITIES AND SYSTEMS

OCTOBER 1976

FINAL REPORT: JANUARY 1976 - JUNE 1976

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AIR FORCE CIVIL ENGINEERING CENTER
(AIR FORCE SYSTEMS COMMAND)
TYNDALL AIR FORCE BASE
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Air transportable shelters are vital elements in present USAF weapon systems, but standardization is needed. In 1975 a Joint Committee on Tactical Shelters (JOCOTAS) was established by DOD to effect this standardization: This report summarizes the USAF effort in this regard. Configuration requirements are analyzed in four major areas: transportation, natural environment, threat-imposed environment, and special mission considerations. Increasing sophistication of weapon systems, the declining number of

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overseas bases, the increasing use of airlift instead of sealift, Soviet emphasis on mobility, and other indicators--all support the conclusion that USAF use of air transportable shelters will increase, possibly to as many as 7500 annually in 1985. An outline of requirements for a family of shelters to serve 1985 USAF needs is developed. It is recommended that this report be forwarded to the USAF Tactical Air Command for reference in preparing a Required Operational Capability (ROC), and to the JOCOTAS for review and possible application in the DOD tactical shelter program.

PREFACE

This report was prepared by the Air Force Civil Engineering Center, Tyndall Air Force Base, Florida, under job order 2101 2002. The report was written while the author was a student at the Armed Forces Staff College, Norfolk, Virginia.

This report summarizes work done between January 1976 and June 1976. James R Van Orman was project officer.

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be releasable to the general public including foreign nations.

This technical report has been reviewed and is approved for publication.

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SECTION I

INTRODUCTION

Air transportable shelters have been used increasingly by the United States Air Force (USAF) to support tactical operations and contingencies since their initial use in the late 1940's. These shelters are presently used for a variety of missions: mobile hospitals, weather stations, photo processing and interpretation, communications, aircraft maintenance, approach and landing control, and many other applications.[1]

WHAT IS AN AIR TRANSPORTABLE SHELTER?

Many different terms have been used in reference to these shelters, such as air mobility shelters, electronic ground equipment shelters, tactical shelters, and lightweight relocatable shelters. Each of these terms may have a slightly different meaning. For the purpose of this report, the term "air transportable shelter" has been selected, with a rather broad definition: a facility which can be readily transported by most USAF transport aircraft, which can be erected or made operational in a few hours by the personnel who will use the shelter, and which is utilized to provide protection in the field to personnel and/or equipment. A simple tent, for example, is a form of air transportable shelter under this definition. Various other forms are identified in Figure 1.

Primary emphasis in this study is on the hardwall shelters identified by the Department of Defense (DOD) as "tactical shelters." The publication definition is:

> "Tactical shelter - a presized rigid/expandable, transportable structure designed to meet functional requirements by providing a live-in/work-in capability. (Specifically exempted - fabric wall shelters, air-supported structures, refrigerated shelters, modular or prefabricated structures designed to be shipped to the theater

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1. U.S., Departments of the Army, the Navy and the Air Force, Joint Services Catalogue of Pre-engineered Facilities which are Retrievable and Relocatable (Washington: 1973), (Army Pam 415-2, Navy Fac P-431, Air Force Pub 86-10) pp. 1-0001 to 1-0101.

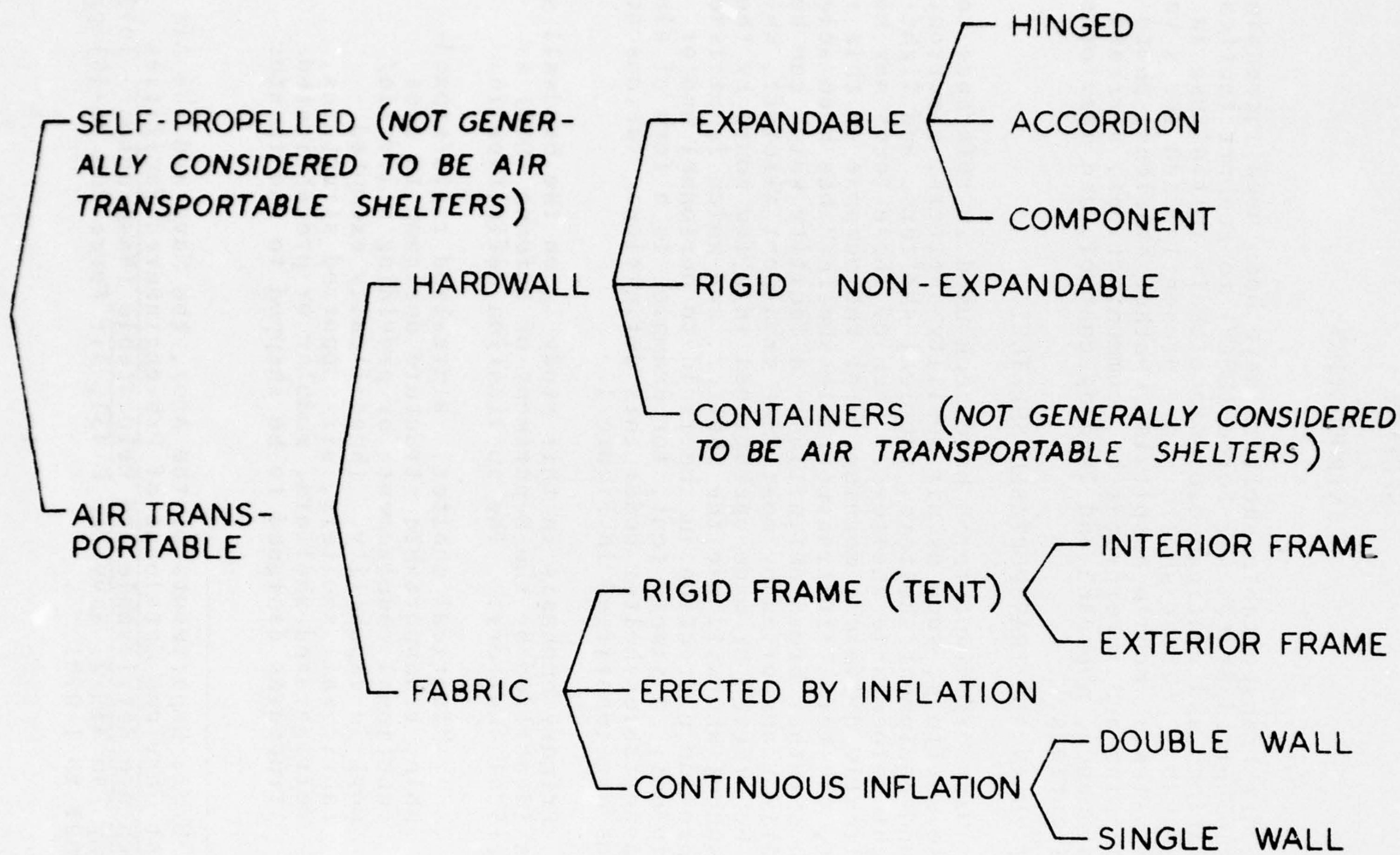

Figure 1. Some Forms of Air Transportable Shelters

of operations and assembled with engineer unit support, and containers.)[2]

These "tactical shelters" are used most often for sheltering electronic equipment and other ground support equipment, but are also used for many other functions such as latrines, kitchens, billeting, and aircraft hangars. By far the largest single collection of air transportable shelters (about 2000) in the USAF is allocated for Bare Base. The Bare Base collection of shelters and other equipment makes up what is essentially a complete, portable, tactical airbase which can be deployed worldwide and which can be made completely operational within 72 hours after the initial aircraft load lands at the deployment base.[3]

PAST EXPERIENCE

Unfortunately, most air transportable shelters have been developed for the unique requirements of a particular mission or system, rather than for a variety of missions. This has resulted in a proliferation of types and sizes of shelters which has been costly in development and in logistics and maintenance as well.

Another problem which has resulted from the practice of "tailoring" shelters for very specific uses, is that an adequate shelter is not available when an urgent new mission is introduced. As a result, the development process is often compressed to unreasonable limits, and inadequately developed shelters (or improperly applied shelters) are procured in order to meet the "operational ready" date. The following example illustrates the dangers of this practice:

During the early stages of the buildup in South Viet Nam in 1964, an urgent USAF requirement was identified for quickly-erectable covered storage. No existing USAF shelters could satisfy the requirement. After examining a number of commercial and military shelters, the USAF procurers decided that a dual-wall air inflatable shelter

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2. U.S., Departments of the Army, the Navy and the Air Force, Department of Defense Tactical Shelter Program (Washington: 1976), Draft Regulation, p. A-10.

3. Carstensen, John P., "Bare Base -- Key to Air Force Mobility," Military Engineer, 62(May-June 1970)pp.168-169.

which had been previously developed by the United States Army would suffice. The shelter was 48 feet (14.4m) wide and was shaped in a hemicylinder, similar to the old "quonset huts." Made up of modular inflatable sections, the shelter could be put together in the field in virtually any length of 12 foot (3.6 m) increments, simply by connecting the sections together. Being inflatable, such shelters could be erected with a minimum of manpower in a few hours. Moreover, the shelters had been "proven" with extensive development and field testing at several installations in the United States.[4]

The Army specifications were modified to reduce the manufacturing costs (an unfortunate move), and a contract was awarded to a previously unknown shelter manufacturer, for 384 shelters. The total cost of the purchase was $8,903,120. Minimal testing was conducted, because of the previous Army testing.[5]

The experience in the hot, humid climate of South Vietnam was disastrous. The shelters literally "came apart at the seams" due to failures of the adhesive and the modified joint construction. The blowers failed repeatedly after only a few hours of operation, causing the shelters to deflate. The pressure regulation system was also faulty. As a result, the shelters were declared unsuitable by the Field Commander and were discarded.[6]

Overall, the shelter project was a total failure, due to inadequate attention to technical requirements. Although it was subsequently shown that a properly-constructed shelter would perform satisfactorily in the same environment, air inflatable shelters had received a bad name and there was a great reluctance to use anything similar to the failed

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4. Van Orman, James R., Dual Wall Air Inflatable Shelter Modifications, Final Test Report AFCEC-TR-72-01, (Tyndall AFB, Florida: September 1972), p. 2.

5. Ibid., p. 3.

6. Morrisey, Edward J., <u>Failure Analysis and Corrective Action for Dual Wall, Air Inflatable Structure, Technical Memorandum MAA-TM-70-8</u>, (Wright-Patterson AFB, Ohio: September 1970), p. 12.

shelters. Even today, 12 years later, air inflatable shelters are practically nonexistent in the USAF.[7]

The Bare Base system also experienced some shelter development problems as a result of the forced compression of development time. The need for a fully-developed family of "universal" shelters has been demonstrated numerous times in many different systems.

RECENT DEVELOPMENTS

A 24 May 1974 memorandum from the DOD Director of Defense Research and Engineering (Appendix A) states:

> "It is becoming increasingly apparent that the shelter . . . area is rapidly growing into a major support function that requires closer coordination during the development phases . . ."

As a result of this memorandum, a Joint Committee on Tactical Shelters (JOCOTAS) was established which, in April 1975, drafted the charter in Appendix B. Charged with "...formulating and executing an integrated program of tactical shelter research, development, testing and engineering to support the military services and other DOD components,"[8] the JOCOTAS was formally established and the charter was approved by a memorandum from the Deputy Secretary of Defense in August 1975. A tentative joint regulation was prepared by the joint committee; it is expected to be approved by the Services this month (May 1976).

The joint committee has been tasked to develop a comprehensive program to insure standardization of shelters in DOD. A family of shelters will, presumably, be developed to facilitate standardization. In order to develop a usable family of shelters each Service will need to identify specific requirements.[9]

In the USAF, the need to correlate all shelter research and development activities was manifest as early as 1972, when the Air Force Civil Engineering Center (AFCEC) at

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7. Ibid., p. 4.

8. U.S., Departments of the Army, the Navy, the Air Force and the Marine Corps, Department of Defense Tactical Shelter Program (Washington: 1975), Draft Charter, p. 1.

9. Draft Regulation on Tactical Shelters, pp. 1-22.

Tyndall AFB, Florida, was designated by Air Force Systems Command as the "focal point" for such activities.

In 1973 AFCEC and the National Bureau of Standards (NBS) initiated a cooperative three-year effort to evaluate existing shelter performance and to develop general structural criteria for shelter design. In Fiscal Year (FY) 1975 the effort was delayed for one year due to funding limitations, but the effort was resumed in FY 1976. Computer models for several general types of air transportable shelters have been developed for evaluating various structural factors.

One of the major considerations in shelter design is the selection of materials and fabrication techniques. Recognizing that many new materials are becoming available which show promise for future shelter construction, a materials research firm (Applied Engineering Resources, Inc) was contracted in 1974 to identify the most promising materials and fabrication techniques for shelter construction in the 1980's. This effort was accomplished under the management of the Air Force Weapons Laboratory (AFWL), in cooperation with AFCEC.[10]

PURPOSE OF THIS REPORT

Considering, then:

(1) the establishment of a DOD-sponsored committee for integrating shelter R & D,

(2) the NBS/AFCEC development of structural evaluation criteria for shelter desig.., and

(3) the identification of promising materials and fabrication techniques for future shelter construction,

it appeared that data were needed in one more area in order to outline the conceptual design of a family of shelters which would meet future USAF requirements. The lacking data were in the area of operational requirements--specifically, the sizes, shapes, and other configuration requirements. The need for determining the approximate numbers of shelters required was also evident.

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10. Bedford, Riley, and Jaffe, M., Air Mobility Shelter Concept Study, Technical Report AFCEC-TR-76-XX, (Tyndall AFB, Florida: September 1975), pp. 1-203.

Consequently, these "missing data" areas were examined. It quickly became obvious that some reasonable predictions of these operational requirements could be made, but only in very general terms because the exercise essentially involved predicting the configuration requirements of all future USAF systems.

The purpose of this report, therefore, is to summarize this initial effort to predict USAF operational requirements for air transportable shelters for 1985 and beyond. This report is not the equivalent of a Required Operational Capability (ROC), but could form the basis for one.

SECTION II

MOBILITY--KEY TO THE FUTURE

INCREASING USE OF AIR TRANSPORTABLE SHELTERS

To estimate the future requirements of anything is a formidable job. "In those deliciously ironic words purported to be a Chinese proverb: To prophesy is extremely difficult--especially with respect to the future."[11] Nevertheless, some predictions are necessary simply because equipment cannot be obtained instantaneously. Development and acquisition necessarily take years to accomplish. Consequently, we must start preparations now for the shelters we will have in the 1980's.

Historically, shelters have had a lifetime of about 3 to 10 years, depending primarily upon the amount of rough handling which they have received. Using this as a general guide, it is apparent that shelters which have already been delivered must be replaced in the mid 1980's, if the present capability is to be maintained. Of course, existing systems which use shelters will be obsolete by then. Presumably, shelters will also be required for new systems which will replace the obsolete systems. It is also apparent that shelters will be used in many new applications in the future.

Weapon systems are becoming increasingly complex and sophisticated. According to all indications, this trend of increasing sophistication will continue in the future. As systems increase in complexity, they increase in support requirements. The support equipment usually requires some protection from the hostile environment; this protection is often provided by a shelter. It appears, then, that the number of shelters is bound to increase in the foreseeable future. Interviews with individuals who have been directly involved with the shelter business for the past 5 to 25 years substantiate the fact of this steady increase since 1950, although precise statistics are not available.

One of the reasons that few significant statistics have been kept on shelters is that the shelters have generally been considered integral parts of "systems", rather than as separate units. Besides causing a record-keeping problem, this has also complicated the standardization objectives. This "unity" of the system is in accordance

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11. Toffler, Alvin, Future Shock (New York: Random House, 1970), p. 7.

with the system engineering practice of optimizing system performance, sometimes at the expense of component performance. The validity of this concept is accepted; however, it is suggested that use of standard shelters will optimize system performance, in the long run. Experience has shown that, except in a very few instances, the problems caused by using non-standard shelters have far outweighed the initially apparent advantages.

Another factor has recently effected a substantial increase in the number of air transportable shelters, and will presumably have the same effect in the future: the continuing threat of forced installation abandonment. We have been forced to abandon valuable facilities in a number of countries in recent years. (The number of overseas USAF bases was 69 in 1968, 52 in 1971 and 37 in 1976.) Loss of facilities is particularly distasteful when they are gained by the enemy such as in Vietnam. For this reason it is expected that more and more portable facilities will be used instead of fixed facilities at all overseas locations, particularly when expensive equipment is involved. Use of air transportable facilities has the obvious advantage of allowing recovery of the investment (and precluding use by the enemy), even when evacuation must be accomplished on very short notice. Because of this threat, air transportable shelters are now considered for every new electronic system which requires a facility.

Table 1 lists the USAF electronic systems which are presently in development or acquisition which will have air transportable shelters.

The development of the Bare Base concept has significantly broadened the scope of air transportable shelters. In addition to adding approximately 2000 shelters to the inventory, Bare Base has created a new dimension by providing a portable tactical airbase. Consequently, even systems which require substantial base support such as electrical power, potable water, specialized maintenance shops, or housing and dining facilities for large numbers of personnel, now have the potential of going to approximately 1400 sites worldwide--essentially any place that has a reparable runway. Many of these systems are already being packaged into air transportable shelters for worldwide deployment, as indicated in Table 1.

There is also a trend toward transporting more equipment overseas by air instead of by sea. Understandably, this trend is particularly evident during crisis or hostile situations. From 1964 to 1969, for example, U.S. military airlift increased

TABLE 1. ELECTRONIC SYSTEMS IN DEVELOPMENT OR ACQUISITION WHICH WILL HAVE AIR TRANSPORTABLE SHELTERS

System No.	System Name
404L	Traffic Control and Landing System (TRACALS)
407L	Tactical Air Control System (TACS)
428A	Tactical Information Processing and Interpretation System (TIPI)
433L	Weather Observing and Forecasting System
450A	Tactical LORAN
478T	Combat Theater Communications
485L	Tactical Air Control System Improvements (TACSI)
490L [a]	Overseas AUTOVON Switches
633A	Cobra Dane
681E	Base and Installation Security System (BISS)
968H	Joint Surveillance System (JSS)
1205 [a]	Air Force Satellite Communication System (AFSATCOM)
1213	Airborne Weather Reconnaissance System (AWRS)
2024	Secondary Surveillance Radar Collision Avoidance System (SSR-CAS)
XXXX [a]	Air Force World-wide Military Command and Control System (AFWWMCCS)
XXXX	Weather Systems Planning
XXXX [a]	Digital European Backbone System (DEBS)
XXXX [a]	Air Traffic Control Planning
XXXX	Advanced Tactical Command and Control
XXXX	Air Force Base Information Transfer System (AFBITS)

[a] Decision to use, or not to use, air transportable shelters is still pending.

from 197,000 to 725,000 tons (175,000 to 650,000 metric tons) annually, an increase of 268 percent. See Figure 2. An even more significant trend is the increase in air shipments in time of relative peace. Comparing the pre-Vietnam years (1962 to 1965) to the post-Vietnam years (1973 to 1976); for example, airlift had a net increase of about 70 percent, while sealift actually decreased about 18 percent.[12]

The primary reason for the shift from sealift to airlift in peace time is, presumably, the declining cost of airlift effected by the newer aircraft. The dropping costs can be illustrated by comparing rates for transporting a ton from Kelly AFB, Texas, to Yokota, Japan: With the piston-engine C-124, the cost was 849 dollars, the Lockheed jet C-141 dropped this to 338 dollars[13] and the cost for the same job with a C-5 is 148 dollars.[14]

Will this trend of increasing air transport continue in the future? Most planners believe it will. Henry Still states that, "It is most likely that 80 to 90 percent of all commodities . . . will be shipped long distance by air 30 years from now (1968)."[15]

Air transportability of systems and shelters must increase to keep pace with the rest of the military world. Response times are becoming more and more demanding--to get there the "first with the most." It is interesting to note the emphasis by one Soviet writer on this point:

> "Thus, air mobilization has objectively led to a number of essential changes in the structure of modern armies and in the theory and practice of military art. Like the great role played by

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12. U.S., Congress, House, Committee on Armed Services, The Posture of Military Airlift. Hearings before the Research and Development Subcommittee, 94, Cong., 1975, p.109; U.S., Dept. of the Navy, Military Sealift Command, Financial and Statistical Reports FY 1975, 3 Oct 1975, pp. 7-8.

13. Still, Henry, Man: The Next 30 Years (New York: Hawthorn Books, 1968), p. 89.

14. US Senate commitee on expenditures, DOD appropriations -- FY 76, 94th Congress, 1st session 1975, Part 4 -- Air Force p. 755.

15. Still, Henry, Man: the Next 30 Years (New York: Hawthorn Books, 1968), p. 89.

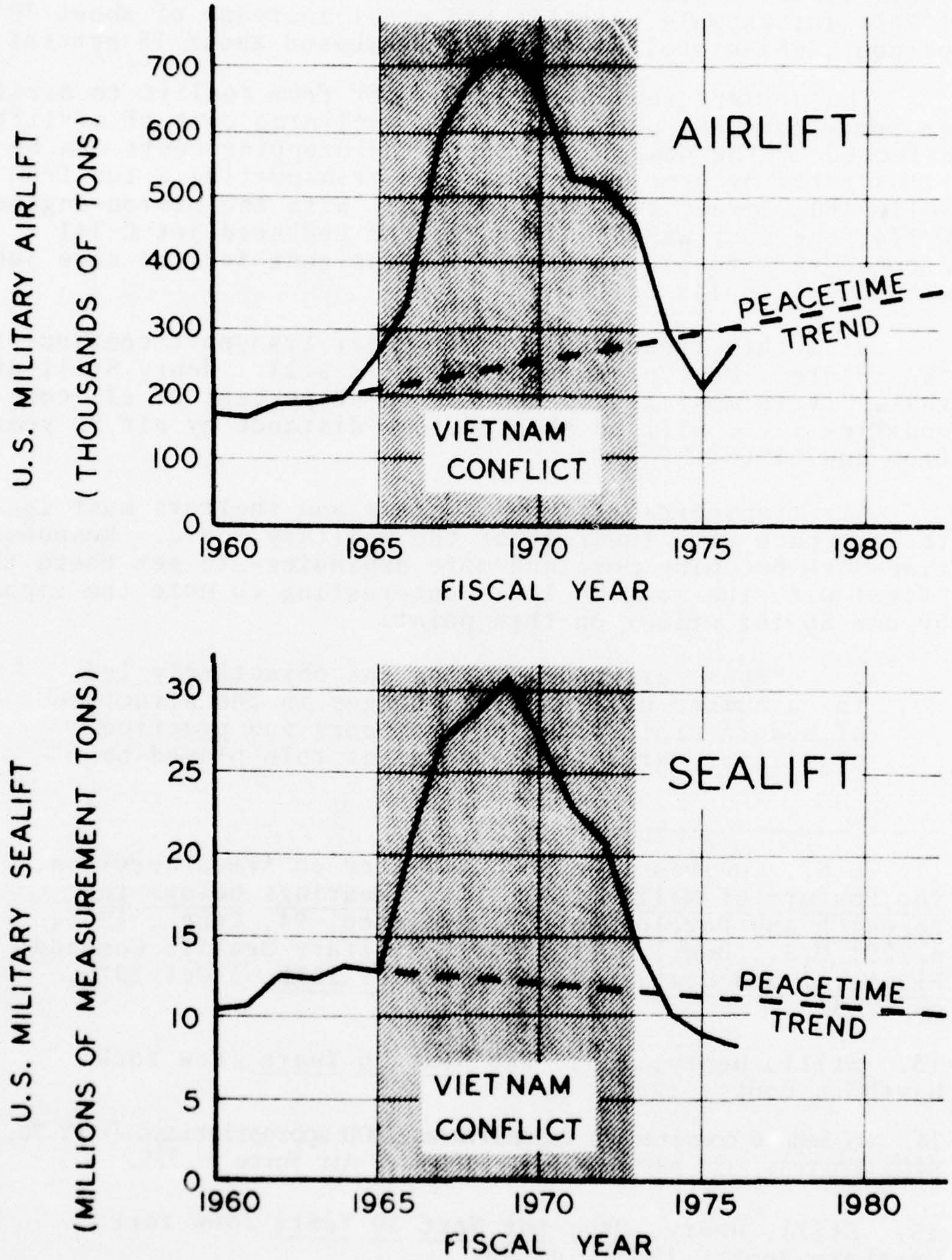

Figure 2. Airlift and Sealift Comparisons

the mechanization of armies during the Second World War, the degree of the air mobilisation of modern...(armed forces) may become the most important criterion of their suitability to modern conditions."[16]

Considering, then, (1) The present 3-10 year lifetime of shelters; (2) The increasing sophistication of systems, and the consequent need for more and more shelters; (3) The progressive increase in numbers of shelters produced over the past 25-30 years; (4) The declining number of overseas USAF bases, and the threat of losing more facilities; (5) The great potential for shelters opened up by the Bare Base concept; (6) The increasing use of airlift instead of sealift, in both peace and war; and (7) The Soviet emphasis on air transportability--it appears that the number of air transportable shelters required in the future will increase substantially. While it is difficult to predict actual numbers because of the many parameters involved, it appears that the USAF air transportable shelter production rate in 1985 will be two to five times the present rate. Since about 1500 shelters are produced annually for the USAF at present, it appears that approximately 3000 to 7500 air transportable shelters will be required by the USAF annually by 1985.

USE OF COMMERCIAL AND OTHER SERVICE SHELTERS

An alternative which must be considered in the future is the use of commercial shelters instead of the present practice of designing shelters specifically for military applications. Avoidance of the high cost of military research and development, and the lower per-unit costs effected by a larger market are certainly desirable. However, the probability of using standard commercial shelters for military applications must be estimated rather low, on the basis of past experience and a comparison of performance requirements. Except in a few areas (such as air-inflatable shelters, portable latrines, and small refrigeration shelters), the civilian community has simply not had a requirement for portable shelters. Particularly in the case of air-transportable shelters, use by the civilian community has been nil. Many shelters which are designed only for truck or rail transport can be shipped by air, but the weight and inefficient size penalties are often too great to make their use practicable.

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16. Belov, M., "Air Mobilization of Modern Armies," Soviet Military Review (Oct 1975), p. 15.

Another problem with using non-military shelters is that they generally are not designed to withstand the severe natural and imposed environments to which military shelters are subjected. For example, few commercial shelters would last very long after smashing through a dense jungle road for several miles, operating at 120°F (49°C) and 80 percent humidity, and then subjecting it to 5 psi (0.34 atm) blast overpressure.

An additional problem with using commercial shelters is the internal configuration. Very few commercial shelters, for example, are adequately designed for installation of sophisticated equipment such as computers or electronic equipment inside and for protection of the equipment during transport and operation.

A few sophisticated commercial shelters have been developed recently to provide protection to electronic equipment for microwave relay stations, on-site construction offices, temporary housing for telecommunications equipment, and other uses. (Most of these shelters have, incidentally, been produced by manufacturers of military shelters, using the expertise developed for military programs.)

In summary, it is felt that extensive use of standard commercial air transportable shelters by the USAF is not promising for the next 5 to 10 years, but the industry should be monitored for new developments.

The use of air transportable shelters developed by the other U.S. military services for USAF applications is much more likely. Shelters such as the U.S. Army's S-280 and S-141 electronic equipment shelters have been used by the USAF in the past and will, presumably, be used in the future wherever they are advantageous. The recently-established Joint Committee for Tactical Shelters (JOCOTAS) is expected to increase the practice of designing shelters to meet multiple mission requirements for all the services. The increasing communication and standardization with the military services of other countries will, hopefully, result in common development and use of a number of air-transportable shelters.[17]

THE CRITICAL PARAMETERS

Looking into the future of air-transportable shelters

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17. *Draft Regulation on Tactical Shelters*, pp. 1-3.

immediately raises the important question: Which parameters are important? An examination of many different characteristics has led to the conclusion that the critical parameters can be categorized as follows:

1. Transportation

2. Natural environment

3. Threat-imposed environment

4. Special mission requirements

Each of these subjects is treated in some detail in the following sections.

SECTION III

TRANSPORTATION

Perhaps the most important determinant of shelter characteristics is the transportation consideration. While at first this may seem to be a fairly simple problem, it is, in fact, extremely difficult, for several reasons. First of all, a shelter must be capable of transport by at least several modes, so it must be designed to withstand the stresses and strains imposed by and be configured for each of these. Second, the stresses imposed by transport are much greater than most people realize (the acceleration forces encountered during rail transport, for example, are as high as 40 g's.) In fact, shelters are often subjected to greater forces than aircraft are.

Third, the shelter must also be transferred from one mode to another--requiring extensive handling by many different kinds of equipment. And the forces imposed by handling can also be severe--as attested by anyone who has watched a crane operator drop an article from several feet above the ground.

Fortunately, considerable headway has been made in recent years in at least one area: international standardization of the physical configuration of shipping containers. The standard 8 x 8 x 20 foot (2.4 x 2.4 x 6 m) intermodal container specified by the International Organization for Standardization (ISO) and the American National Standards Institute (ANSI) is now extensively used by both military and civilian agencies.[18] Overall dimensions and handling attachments are thus standardized and allow the containers to be "stacked" up to seven high. These standard containers weigh approximately 3580 pounds (1610 kg) each (empty) and can be shipped by sea, rail, highway, by C-130, C-141, and C-5 aircraft, and by some helicopters. The new container ships emphasize the dramatically increasing trend toward containerization, since the first containers were used in 1957. "On a worldwide basis, 28 percent of DOD export ocean cargo was containerized in 1970. Containerization increased to 44 percent in 1971 and to almost 50 percent in 1972."[19]

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18. Weingarten, Joseph L., Impact of Intermodal Containerization on USAF Cargo Airlift, Technical Report ASD-TR-72-76. (Wright-Patterson AFB, Ohio: August 1972), pp. 4-85.

19. "Transportation Policy," Commanders Digest, 13 (3 May 1973), p. 2.

Eventually, it is estimated that 75 percent of export ocean cargo will be containerized.[20]

Unfortunately, these standard containers are rarely satisfactory for use as shelters in the field, because they do not meet the mission requirements. While they are transportable by most of the civilian modes of transport, they generally can not be transported over rough terrain by any of the common ground vehicles: M-35 truck, mobilizer, or adverse terrain forklift. It is important here to note the DOD instructions on "containerization" of shelters:

> "Shelters and/or special purpose vans . . . developed for an operational requirement such as automatic data processing vans, repair machine shops, communication vans, etc. . . . will conform to ANSI/ISO container specifications to the extent practicable."[21]

There is, however, a possible loophole in this instruction, under the definition of "shelters and/or special-purpose vans":

> "Excluded from this definition is equipment designed basically for transportation or fortification which may provide an environmental protection capability as an inherent but secondary feature."[22]

On the basis of these instructions, and the continuing trend toward containerization in the commercial world and DOD, increasing use of the ANSI/ISO container configuration for shelters is expected.

We will now examine the transportation requirements for shelters in each of the following modes: air, ground, sea, and transfer.

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20. "Army, DOD's Single Manager," Commanders Digest, 13 (3 May 1973), p. 6.

21. U.S., Department of Defense, Ownership and Use of Containers for Surface Transportation and Configuration of Shelters/Special Purpose Vans (Washington; 1971), (DOD Instruction 4500.37), p. 8.

22. Ibid., p. 10.

AIR TRANSPORT

Air transportable shelters, by definition, must be transportable by air. Essentially, this means by transport aircraft or helicopter. Transport aircraft and helicopters in the inventory are listed in Appendix C.

Looking to the future, three inventory aircraft are expected to make up the primary transport fleet in 1985: the C-130, C-141 and C-5 aircraft.[23] The C-130 is essentially, the baseline transport aircraft, but the C-130's are aging.

Several alternatives are being considered for replacement of the C-130's. Probably the most likely candidate is the Advanced Medium STOL Transport (AMST) which would first be available about 1985.[24] The primary characteristics of the AMST, C-130, C-141 and C-5 aircraft are shown in Tables 2 and 3.

One problem in transporting shelters by air is that roller systems in the aircraft are designed for moving pallets or other flat bottom cargo, but shelters generally have "skids" which are used to absorb some of the shock in handling and to supposedly allow movement by dragging in the field. And a further complicating factor is that none of the roller systems are exactly alike. These problems caused the Bare Base Equipment System Program Office to use exclusively flat bottom shelters. However, some of the "maverick" roller systems are being phased out, and by 1985 it is expected that a properly-designed skid system on a shelter would be compatible with most roller systems. The shelter could be mounted on pallets, if necessary, to facilitate loading and unloading. Consequently, it is felt that flat-bottom shelters are preferable for air transport, but that shelters with skids could be shipped.

Shelters configured in the shipping mode like intermodal containers can be transported by all of the primary 1985

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23. Weingarten, p. 2.

24. Rumsfeld, Donald H., Secretary of Defense, Defense Program and Budge for 1977, submitted to the House Committee on Armed Services, 27 Jan 1976, p. 203.

TABLE 2. CHARACTERISTICS OF 1985 TRANSPORT AIRCRAFT (ENGLISH UNITS)[25]

Aircraft	Maximum payload (and corresponding range)	Payload with (maximum range)	Cargo Compartment			463L Pallet Capacity
			Height	Width	Length	
C-130H	43,811 lb (2487 mi)	20,000 lb (5135 mi)	9 ft 1 in	10 ft 3 in	41 ft 5 in	6
C-141	70,847 lb (4080 mi)	32,574 lb (7050 mi)	9 ft 1 in	10 ft 3 in	70 ft 0 in	10
C-141 Stretched	Unknown	Unknown	9 ft 1 in	10 ft 3 in	103 ft 6 in	13
C-5	220,967 lb	112,600 lb	13 ft 6 in	19 ft 0 in	121 ft 1 in	36
AMST	78,000 lb (Range unknown)	Unknown	11 ft 4 in	11 ft 8 in	47 ft 0 in	7

[25] Primary sources of data: Janes All the World's Aircraft and Air International.

TABLE 3. CHARACTERISTICS OF 1985 TRANSPORT AIRCRAFT (METRIC UNITS)[25]

Aircraft	Maximum payload (and corresponding range)	Payload with (maximum range)	Cargo Compartment			463L Pallet Capacity
			Height (cm)	Width (cm)	Length (cm)	
C-130H	19,878 kg (4000 km)	9075 kg (8260 km)	277	310	1260	6
C-141	32,145 kg (6565 km)	14,780 kg (11,345 km)	277	310	2133	10
C-141 Stretched	Unknown	Unknown	277	307	3154	13
C-5	100,257 kg	51,090 kg	410	580	3690	36
AMST	35,390 kg (Range unknown)	Unknown	345	355	1432	7

[25] Primary sources of data: Jane's All the World's Aircraft and Air International.

transport aircraft.[26] Two 8 x 8 x 20 foot (2.4 x 2.4 x 6 m) shelters could be transported by C-130, three by C-141, five by "stretched" C-141, twelve by C-5 and two by AMST.

The other mode of air transport is by helicopter, which is used to a much lesser extent than aircraft. Helicopters are generally employed to move shelters relatively short distances in extremely rough terrain, such as on mountain tops.

Only one helicopter in the present USAF inventory (CH-53) is capable of lifting a loaded shelter weighing 5000 to 25,000 pounds (2300 to 11,300 kg). However, there are many commercial or Army helicopters which could easily handle the job (including, for example, the CH-47 and CH-54 helicopters). (See Table 4.)

In order to enable helicopters to easily pick up containers and container-configured shelters,

> "Boeing . . . has designed a special container lifting device that can pick up containers 20 through 40 feet long. The device weighs approximately 1,200 pounds and can be used with CH-47 and CH-54 helicopters . . ."[27]

The substantial capacities of existing and developmental helicopters indicate that there are no serious restrictions on shelter configuration posed by this mode of transport.

SEA TRANSPORT

It is expected that shelters in 1985 must be capable of sea transport, since at present approximately 96% of all overseas DOD cargo is shipped by sea,[30] and air transport is presently used only in special cases. It is quite possible, for example, that a shelter would be deployed by air but would return by sea.

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26. Price, Michael H., and Weingarten, Joseph L., Aerial Port Container Handling Equipment Requirements and Air Transportability for Intermodal Containers, Technical Report ASD-TR-74-10, (Wright-Patterson AFB, Ohio: May 1974), p. 60.

27. Granger, Louis R., "Heavy Lift," Sealift, (April 1975), p. 22.

30. Weingarten, p. 9.

TABLE 4. AIR FORCE AND ARMY TRANSPORT HELICOPTERS[28, 29]

Service	1975 Inventory	Manufacturer	Designation	Maximum Payload
Air Force	100	Kaman	HH-43	3970 lb (1800 kg)
	50	Sikorsky	HH-3	5000 lb (2300 kg)
	33	Sikorsky	CH-3	5000 lb (2300 kg)
	66	Sikorsky	HH-53C	25,000 lb (11,300 kg)
Army	611	Boeing Vertol	CH-47	25,000 lb (11,300 kg)
	91	Sikorsky	CH-37	10,300 lb (4700 kg)
	56	Sikorsky	CH-54	25,000 lb (11,300 kg)
	437	Sikorsky	CH-34	6250 lb (2800 kg)

[28] Inventory data from International Air Forces and Military Aircraft Directory.

[29] Performance data from Jane's All the World's Aircraft 1975-76.

Containerization has revolutionized the commercial sealift industry, and is just starting to have the same effect on military sealift. While non-containerized cargo will presumably always be transportable by sea, the advantages of containerization are substantial in both cost and delivery time.

> "Overall, it is estimated that investment (due to containerization) approximately doubled; however, the reduced manpower resulted in an overall saving of 10 percent. In port, time decreased considerably from 7 days for a break bulk ship to 22 hours for an equivalent containership. Other indirect cost included a reduction by 50 percent of breakage through containerization. Pilferage is negligible via container compared to an average 10 to 15 percent loss via conventional mode."[31]

It is apparent that shelters which are configured in the shipping mode like intermodal containers will be advantageous in the future.

LAND TRANSPORT

Shelters which must be transported over considerable distances overland or by highway are generally carried by truck, trailer, or mobilizer. The other common method for long-distance land transport is by railway. For shorter distances (2 miles/3 km or less), forklifts are sometimes used. Each of these modes of transport has some unique requirements which must be considered.

By far the most common truck used for transporting shelters is the M-35 2-1/2 ton (2.3 t) cargo truck, the characteristics of which are listed in Appendix D. The most significant restriction which this truck imposed upon shelter configuration is the 88 inch (224 cm) wide by 147 inch (374 cm) long bottom dimensions. A relatively new modification of this truck, with fold-down sides, offers expansion of these dimensions to approximately 8 feet by 13 feet (2.4 by 4 m). Since trucks used to transport tactical shelters are generally "dedicated" to that particular job, the advantage of procuring M-35 trucks with the fold-down side modification is apparent.

Trailers are used infrequently for transporting shelters, and do not pose any significant transport problems which are unique.

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31. Ibid., p. 6.

Mobilizers are essentially wheel-axle combinations which can be fastened onto the ends of a shelter in the field, and which then convert the shelter into a kind of trailer. They have been used extensively. One problem with mobilizers is evident when moving a shelter up the ramp of a transport aircraft: The two ends must be gradually moved up and down to prevent scraping or "bottoming out." Another problem is the weight limitations of existing mobilizers: about 12,000 pounds (5400 kg) maximum. For these reasons, many shelter development engineers have expressed the feeling that mobilizers are becoming obsolete.

Rail transport of shelters does not pose any significant weight or dimension restrictions, but the acceleration forces can be as high as 30-40 g's which, of course, can be devastating to a shelter. For this reason rail shipment is often specifically excluded from consideration for shelter transport.

Forklift requirements are discussed on the following page.

TRANSFER FROM ONE TRANSPORT MODE TO ANOTHER

When transporting a shelter from, for example, a CONUS base to an overseas location, it is apparent that it must be transferred several times from one mode to another. Many different kinds of equipment have been used for this purpose: special aircraft loaders, forklifts, cranes, flatbed trailers, and other devices.

The types of equipment used at the aerial port are probably the most important factors concerning mode transfer. An extensive study by Aeronautical Systems Division (ASD) in 1974[32] identified, for various categories of aerial ports, the handling equipment which will be used in 1980 (Figure 3). Essentially, this shows that, as far as weight and dimensions are concerned, virtually all aerial ports will be able to handle 8 x 8 x 20 foot (2.4 x 2.4 x 6 m) size shelters weighing 25,000 pounds (11,300 kg) or less; even mobile aerial ports used at Bare Base locations can handle this size. The problem discussed under Air Transport concerning the bottom configuration of shelters may, however, be a significant problem. Again, a flat bottom shelter may be advantageous, although it appears that a shelter with skids could be handled.

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32. Price, pp. 18, 24.

EQUIPMENT	AERIAL PORT CATEGORY (2)						
	I	II	III	IV	V	VI	VII
70K Transporter/Lift	●				No container handling capability		
70K Forklift	●						
52K Forklift		●	●				●
52K Transporter/Lift		●	● (1)				● (1)
40K Loader (463L)			●				●
25K Loader (463L)				●		●	
Lifting Beam	●	●	●	●		●	●
Container Adapter	●	●	●	●		●	●
Truck Transport	●	●	●	●		●	●
Aircraft Load Aids	●	●	●	●		●	●

NOTES:

(1) Eventually to be replaced with lower capacity K loader.

(2) Category I: Primary aerial container port. Heavy vol.

Category II: Aerial container port. Medium volume.

Category III: Aerial container port. 50K cont. capacity.

Category IV: Aerial port. 35K container capacity.

Category V: No container handling capacity.

Category VI: Mobile aerial port. Equivalent to Cat. IV.

Category VII: Mobile aerial port. Equivalent to Cat. III.

Adapted from ASD-TR-74-10, May 1974.[26]

Figure 3. 1980 Aerial Port Equipment

Forklift-handling of shelters requires some special considerations. Forklifts have been used extensively on some programs, such as Bare Base, where considerable experience has been gained. The 463L 10,000 pound (4500 kg) adverse terrain forklift was primarily used to transport hundreds of shelters from the aircraft unloading area, across the ramp, across the terrain, to the designated operational site for the shelter. It became obvious early in the program that, while a designated forklift was generally used, the shelters should also be compatible with essentially all forklifts. The forklift entries on the sides of the shelter should be at least 4 x 12 inches (10 x 30 cm), spaced 48 inches (120 cm) apart on center. Provisions should be made to prevent damage to the forklift side of the shelter and the bottom when the forklift "bounces" across adverse terrain. To allow maximum handling speed, forklift entries should be located on all four sides. This allows a shelter to be loaded directly into the aircraft cargo area by handling it with a forklift from the end. These provisions can be expensive and should only be considered for shelters which have a fairly high expectation of considerable forklift handling.

Transportation then becomes a most important consideration in determining the configuration of shelters. The next two parameters to be considered, the natural environment and the threat-imposed environment are also important because protection from them is really the reason shelters are used.

SECTION IV

NATURAL ENVIRONMENT

Protection from "the elements"--or, in grossly simplistic terms, to keep the inside in, and the outside out--is perhaps the main function of a shelter. For centuries the tent was considered the only practical facility for protection of personnel and equipment in the field. For the past few decades, however, the increasing sophistication of equipment, and increasing dependence on efficiency of highly trained and specialized personnel, have effected an increasing reliance on more complete protection. A tent provides considerable protection from rain, snow, and wind. But it provides very little protection from extreme temperatures and humidity. Consequently, shelters with rather complete air conditioning are now widely used.

The most difficult aspect of predicting the future environmental requirements for shelters is in identifying reasonable extremes. It would be relatively easy to identify the absolute extremes which will probably occur on the face of the earth for a given period of time, since weather records for most of the world are available. However, designing all shelters to meet all of these requirements would be prohibitively expensive. Wind forces, for example, are known to be as high as 300 mph (480 km/hr) in a tornado. But the probability of a shelter being subjected to wind forces of this magnitude is very close to zero. Even fixed facilities are not designed to withstand these forces because of the high costs of providing structural reinforcement. In air transportable shelters the ever-present problem of weight restrictions must also be considered, and it is evident that some risk must be assumed. While the Air Force apparently does not have an official policy on risk for field equipment, the Army policy is considered to be reasonable:

> "Normally, Army materiel will not be designed, developed, and tested to withstand the absolute extreme climatic conditions which occur in the area. Materiel will be designed, developed, and tested to withstand extreme climatic conditions such that more severe climatic extremes are expected to occur only one percent of the time (hours) in the most extreme month in the most extreme parts of the appropriate areas. . . . This one percent risk policy . . . is

accepted in view of the cost and complexity of designing for the 'absolute' extreme conditions which might occur in an area."[33]

The Army has done an excellent job of summarizing climate conditions for various parts of the world in Army Regulation (AR) 70-38.[34] The climatic categories shown in Tables 5 and 6 have been used in this study.

Referring to the stated risk policy, and the climate conditions described in AR 70-38, Tables 7 and 8 show the worldwide climate extremes.

The probability of deploying a shelter to either an extremely hot or an extremely cold condition is actually quite low, because these conditions tend to occur only in very remote areas, as shown in Appendix E. The probability of deploying a particular shelter in its lifetime to both extremes is even lower. One possible approach, therefore, is to design shelters for relatively moderate conditions, and use "add-on kits," consisting of extra insulation, and additional heaters or air conditioners as necessary. A significant advantage of this "add-on" approach is that a relatively lightweight basic shelter could be deployed initially, if the weather were moderate, with the add-on package deliverable at a later date. The extremes to be used for the "basic" shelter whould be determined on the basis of the climate categories in Tables 5 and 6, cost sensitivity to the extreme conditions, material performance thresholds, the operational simplicity of the add-on kit design, and other factors.

Besides the natural environment, another environment must be considered for military shelters: the threat-imposed environment. This area is discussed in the following section.

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33. U.S., Department of the Army, Research, Development, Test, and Evaluation of Materiel for Extreme Climatic Conditions (Washington: 1969), (AR 70-38), p. 1-2.

34. Ibid., p. 2-2.

TABLE 5. WORLDWIDE CLIMATE CATEGORIES (ENGLISH UNITS)[a]

Climatic Category	Operational Conditions: Ambient Air Temperature (°F)	Operational Conditions: Solar Radiation ($Btu/ft^2/hr$)	Operational Conditions: Ambient Relative Humidity (Percent)	Storage and Transit Conditions: Induced Air Temperature (°F)	Storage and Transit Conditions: Induced Relative Humidity (Percent)
1 Wet-Warm	Nearly constant 75	Negligible	95 to 100	Nearly constant 80	95 to 100
2 Wet-Hot	78 to 95	0 to 360	74 to 100	90 to 160	10 to 85
3 Humid-Hot Costal Desert	85 to 100	0 to 360	63 to 90	90 to 160	10 to 85
4 Hot-Dry	90 to 125	0 to 360	5 to 20	90 to 160	2 to 50
5 Inter-mediate Hot-Dry	70 to 110	0 to 360	20 to 85	70 to 145	5 to 50
6 Inter-mediate Cold	-5 to -25	Negligible	Tending toward saturation	-10 to -30	Tending toward saturation
7 Cold	-35 to -50	Negligible	Tending toward saturation	-35 to -50	Tending toward saturation
8 Extreme Cold	-60 to -70	Negligible	Tending toward saturation	-60 to -70	Tending toward saturation

[a]Adapted from AR 70-38

TABLE 6. WORLDWIDE CLIMATE CATEGORIES (METRIC UNITS)[a]

Climatic Category	Operational Conditions: Ambient Air Temperature (°C)	Solar Radiation (kg-cal/m^2/hr)	Ambient Relative Humidity (Percent)	Storage and Transit Conditions: Induced Air Temperature (°C)	Induced Relative Humidity (Percent)
1 Wet-Warm	Nearly constant 24	Negligible	95 to 100	Nearly constant 27	95 to 100
2 Wet-Hot	26 to 35	0 to 8.43	74 to 100	32 to 71	10 to 85
3 Humid-Hot Costal Desert	29 to 38	0 to 8.43	63 to 90	32 to 71	10 to 85
4 Hot-Dry	32 to 52	0 to 8.43	5 to 20	32 to 71	2 to 50
5 Inter-mediate Hot-Dry	21 to 43	0 to 8.43	20 to 85	21 to 63	5 to 50
6 Inter-mediate Cold	-20 to -32	Negligible	Tending toward saturation	-23 to -34	Tending toward saturation
7 Cold	-37 to -46	Negligible	Tending toward saturation	-37 to -46	Tending toward saturation
8 Extreme Cold	-51 to -57	Negligible	Tending toward saturation	-51 to -57	Tending toward saturation

[a]Adapted from AR 70-38

TABLE 7. WORLDWIDE CLIMATE EXTREMES (ENGLISH UNITS)

MAXIMUM AMBIENT AIR TEMPERATURE: Four continuous hours with an ambient temperature, 4 to 6 feet above the ground, above 120°F, with an extreme temperature of 125°F for not more than 1 hour. Corresponding windspeed of 0 to 10 knots, and relative humidity of 0 to 74 percent
MINIMUM AMBIENT AIR TEMPERATURE: Six continuous hours with an ambient temperature of minus 70°F, with windspeed less than 5 knots, and relative humidity tending toward saturation.
MAXIMUM WIND SPEED: Sustained 5-minute winds of 70 knots, with gusts to 105 knots, measured at the 10-foot level where winds are generally the strongest.
RELATIVE HUMIDITY: 0 to 100 percent.
SOLAR RADIATION: 0 to 360 Btu/ft^2/hour.
MAXIMUM RAINFALL: 9.50 inches in 12 hour period, with intermittent wind speed up to 35 knots. For shorter periods the intensities are 5.50 inches in 1 hour, 1.50 inches in 10 minutes, 1.00 inches in 5 minutes, and 0.45 inches in 1 minute.
MAXIMUM SNOW LOAD: 40 pounds per square foot (psf), if not cleared between snowfalls; 20 psf if cleared between snowfalls.
MAXIMUM SEA SALT FALLOUT: 0.000574 psf (25 pounds/acre) per year.
BLOWING DUST, WORST CASE: 6 X 10^{-9} gm/cm^2, with particles 0.0001 to 0.01 mm diameter, blowing at 35 knots at a 5-foot height.

TABLE 8. WORLDWIDE CLIMATE EXTREMES (METRIC UNITS)

MAXIMUM AMBIENT AIR TEMPERATURE: Four continuous hours with an ambient temperature, 120 to 180 cm above the ground, above 49°C, with an extreme temperature of 52°C for not more than 1 hour. Corresponding windspeed of 0 to 18 km/hr, and relative humidity of 0 to 74 percent.
MINIMUM AMBIENT AIR TEMPERATURE: Six continuous hours with an ambient temperature of minus 57°C, with windspeed less than 9 km/hr, and relative humidity tending toward saturation.
MAXIMUM WIND SPEED: Sustained 5-minute winds of 130 km/hr, with gusts to 195 km/hr, measured at the 300 cm level where winds are generally the strongest.
RELATIVE HUMIDITY: 0 to 100 percent.
SOLAR RADIATION: 0 to 8.43 kg-cal/m^2/hr.
MAXIMUM RAINFALL: 24.0 cm in 12 hour period, with intermittent wind speed up to 65 km/hr. For shorter periods the intensities are 14.0 cm in 1 hour, 3.8 cm in 10 minutes, 2.5 cm in 5 minutes, and 1.1 cm in 1 minute.
MAXIMUM SNOW LOAD: 200 kg/m^2, if not cleared between snowfalls; 100 kg/m^2 if cleared between snowfalls.
MAXIMUM SEA SALT FALLOUT: 2.8 gm/m^2 per year.
BLOWING DUST, WORST CASE: 6 X 10^{-9} gm/cm^2, with particles 0.0001 to 0.01 mm diameter, blowing at 65 km/hr at a 150 cm height.

SECTION V

THREAT-IMPOSED ENVIRONMENT

In a combat situation, shelters may be subjected to dynamic loads and other phenomena which are never experienced in a peaceful situation, except in testing. These requirements must, of course, be properly considered in the shelter design if the system is to survive. The importance of this consideration is particularly evident when one considers that satisfactory performance of the system in this "imposed environment" is probably more critical at that time than at any other.

Even so, consideration of the threat-imposed environment has largely been ignored in the design of air transportable shelters until recently, primarily because it has been assumed that provision of this kind of protection would require prohibitive weight and cost additions. To a large extent, mass is required to dissipate the energy effected by explosions, and mass is not congruent with the weight restrictions of air transport. Consequently, this lack of hardness of air transportable shelters has been reluctantly accepted on the basis that the air transportability feature is more important than protection from weapon effects that can not be precisely predicted anyway. In fact, even buildings of conventional construction are mostly incapable of withstanding any substantial weapons effects.

Another factor is evident: air transportable shelters are needed to support weapon systems which will be deployed to high threat areas. So, it may be argued, the probability of an air transportable shelter being exposed to substantial weapons effects may actually be higher than for conventional buildings. Thus, the quandary appears. Can we afford, in terms of weight and dollars, to provide future air transportable shelters with any reasonable protection from this threat-imposed environment?

There is at least one way in which this quandary can be circumvented: By reinforcing or covering the shelter with local materials to provide additional protection. By this method, the British Army's NBC Shelter, for example, is reportedly capable of withstanding substantial blast loads and other adverse effects of "near-miss nuclear weapons."[35] The major

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35. "The British Army's NBC Shelter," International Defense Review 8 (April 1975), p. 271.

disadvantage of this approach is that it tremendously increases the time required to relocate the shelter, at least by present designs.

Another possible way to overcome this problem is to use a combination of supplemental protective gear ("add-on" kit) and local materials. By this method the shelter could be deployed unprotected, used in the unprotected state while the additional protective gear is built around it and covered with indigeneous materials, and then operated in the protected mode when the construction is completed. When the time arrives for redeployment, the shelter could, conceivably, be simply rolled out through a protective door and relocated. Meanwhile, the supplemental construction could be dismantled for later redeployment (or kept in place if return of the shelter is a possible future event). There seem to be many possibilities for using this idea.

One of the problems involved with protective construction is in identifying the levels of protection to be provided. If the characteristics of a weapon and the distance from the shelter are known, then it is a rather simple matter to determine what the "imposed environment" is, using the extensive instructions which have been developed. The problem is that neither the weapon characteristics nor the location of employment are ever precisely known in a real combat situation. Conversely, if the worst possible combination is assumed, it may be impossible to design adequate protection. Consequently, it is evident that some risk must be accepted and certain levels of protection prescribed, according to the acceptable risk. The USAF is now in the process of developing guidelines for these protective criteria for various kinds of construction in different situations.

A recent study by the US Army Ballistic Research Laboratories has looked at the vulnerability and hardening design requirements of transportable shelters in a tactical nuclear battlefield. A design was developed to modify an S-280 shelter to withstand shock overpressure of 7.1 psi (0.5 atm) and the corresponding thermal effects of a tactical nuclear explosion.[36]

The major protection considerations will now be discussed.

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36. Schuman, William J., Vulnerability and Hardening of Command, Control and Communication Shelter Systems Draft Research Paper, US Army Ballistic Research Laboratories, (Aberdeen Proving Ground, Maryland: January 1976).

NUCLEAR EFFECTS

Most of the effects of nuclear explosions are well known and will not be discussed here. The primary considerations are: the blast overpressure, the thermal radiation, and the radioactive fallout. In addition to these effects, however, there are two lesser known effects which may be of particular importance for future shelters:

> "A nuclear explosion on the battlefield will have both immediate and prolonged effects on communication systems. The extent of these effects will be a function of the yield and altitude of burst . . . Aside from the classical effects of heat, radiation, and blast, two other effects can be expected to degrade communication. The first is signal absorption or blackout, the second is equipment destruction resulting from the effects of an electromagnetic pulse (EMP). The first affects the propagation of the radio frequency signal, while the latter affects the electronic equipment and components processing the signal . . ."[37]

Because of the potential harm to electronic equipment, EMP is considered to be particularly dangerous.

> "The spectrum and waveform of EMP differ from those of any other natural or commonly-used man-made sources. The spectrum is broad and extends from extremely low frequencies into the UHF band. The time waveform indicates a higher amplitude and much faster rise than, for example, the fields generated by a nearby lightning stroke . . . EMP can be viewed as a single, high powered pulse which could induce a harmful current into nearly all types of electronic and electrical equipment. It can severely stress or burn out elements such as diodes, transistors, capacitors, and resistors. It can weaken or burn through wire insulation or dielectric devices that operate on magnetic tapes."[38]

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37. Parlan, L. McGivern, "Electromagnetic Pulse Effects on Tactical Communications: Signal, 28 (April 1974), p. 29.

38. Ibid., p. 30

There are two properties of EMP which make it particularly threatening for electronic shelters:[39]

(1) The extremely great "killing range." The Defense Nuclear Agency reports that EMP is capable of disabling electronic or electrical equipment "as far as 3000 miles (5000 km) from the site of the detonation."

(2) The imperceptibility. "EMP can cause severe disruption and sometimes damage when other prompt weapons effects . . . are all absent."

CONVENTIONAL WEAPON EFFECTS

The effects of conventional weapons are also widely known. Primarily, the considerations in conventional weapon protection are the resistance to blast overpressure and projectile or fragment penetration. Detailed treatment of these considerations is provided in several documents.[40]

CHEMICAL WARFARE EFFECTS

In 1974-75 the USAF conducted an extensive study of the effects of chemical warfare, including the consideration of protection of portable facilities. Of course, the chemical warfare problem is considerably different from the conventional and nuclear considerations. Damage to the shelter itself, for example, is not caused by any of the common chemical agents. Damage to internal equipment is likewise of little concern, except for some "exotic" agents. By far the most important consideration is the protection of personnel from the harmful effects of the toxic agents. The use of individual protective gear inside the shelter is not necessarily adequate either, since the individuals can only wear the gear without exhaustion for perhaps 4 to 6 hours. Then, they must have a place to rest, eat, defecate, etc. Consequently, the USAF study showed, "collective protection" must be provided either continuously or in rest shelters for all individuals. Detailed criteria for these shelters are being developed by AFCEC.

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39. Ibid.

40. U.S., Department of the Army, Military Protective Construction (Nuclear Warfare and Chemical and Biological Operations), (Washington: 1965), (TM 5-311), pp. 2-1 through 2-10.

BIOLOGICAL WARFARE EFFECTS

Biological warfare is not considered to be as great a threat for air transportable shelters as chemical warfare. Primarily, this is because biological agents are considered to be primarily strategic weapons, whereas chemical agents are primarily tactical. (Biological agents generally work rather slowly, but chemical agents have almost instantaneous effects.) As mentioned, air transportable shelters are used primarily for tactical operations. It is also reported that shelters which are designed to provide adequate chemical agent protection are also satisfactory for protecting against biological agents.

SECTION VI

SPECIAL MISSION REQUIREMENTS

In order to end up with a family of shelters which would meet multiple mission requirements, it is evident that the special configuration requirements of these missions must be understood. It is not possible at this point to identify all of these special requirements for all future missions, but the most important considerations can be identified, and a number of observations based on past experience will serve as starting points.

SHELTER SIZE AND SHAPE

Perhaps the most significant shelter feature dictated by the mission is the size of the shelter in the operational mode. To a lesser extent, the shape is also dictated by the mission. It is the mission that determines which of the shelter forms in Figure 1 is most appropriate, if any. While the Joint Committee for Tactical Shelters (JOCOTAS) is only concerned with a rather limited number of these shelters, it is apparent that standardization is desirable for all types.

At a meeting of representatives from each of the shelter using agencies at Tyndall AFB on 9-10 December 1975, the nominal operational sizes shown in Figure 4 were identified as requirements for future tactical shelters.

It was noted by attendees at the meeting that, at present, the equipment required for some of the 8 x 24 x 13 foot (2.4 x 7 x 4 m) and 8 x 24 x 20 foot (2.4 x 7 x 6 m) shelters is too voluminous to fit in one shelter, so use of two shelters in these cases would be satisfactory.

These shelter sizes were determined essentially on the basis of satisfaction with existing shelters. All of these shelters are of a "box" shape, and in order to accommodate equipment racks, it is expected that future tactical shelters must be of the same shape.

In addition to these "tactical shelter" requirements, at least one larger size is required for aircraft maintenance and similar functions. Users have identified the minimum size for aircraft maintenance to be 76 feet wide by 25 feet high by 84 feet long (23 by 7.6 by 25 m), if constructed of circular arch sections as in Bare Base, in order to accommodate two F-4 aircraft. It would, of course, be preferable to have

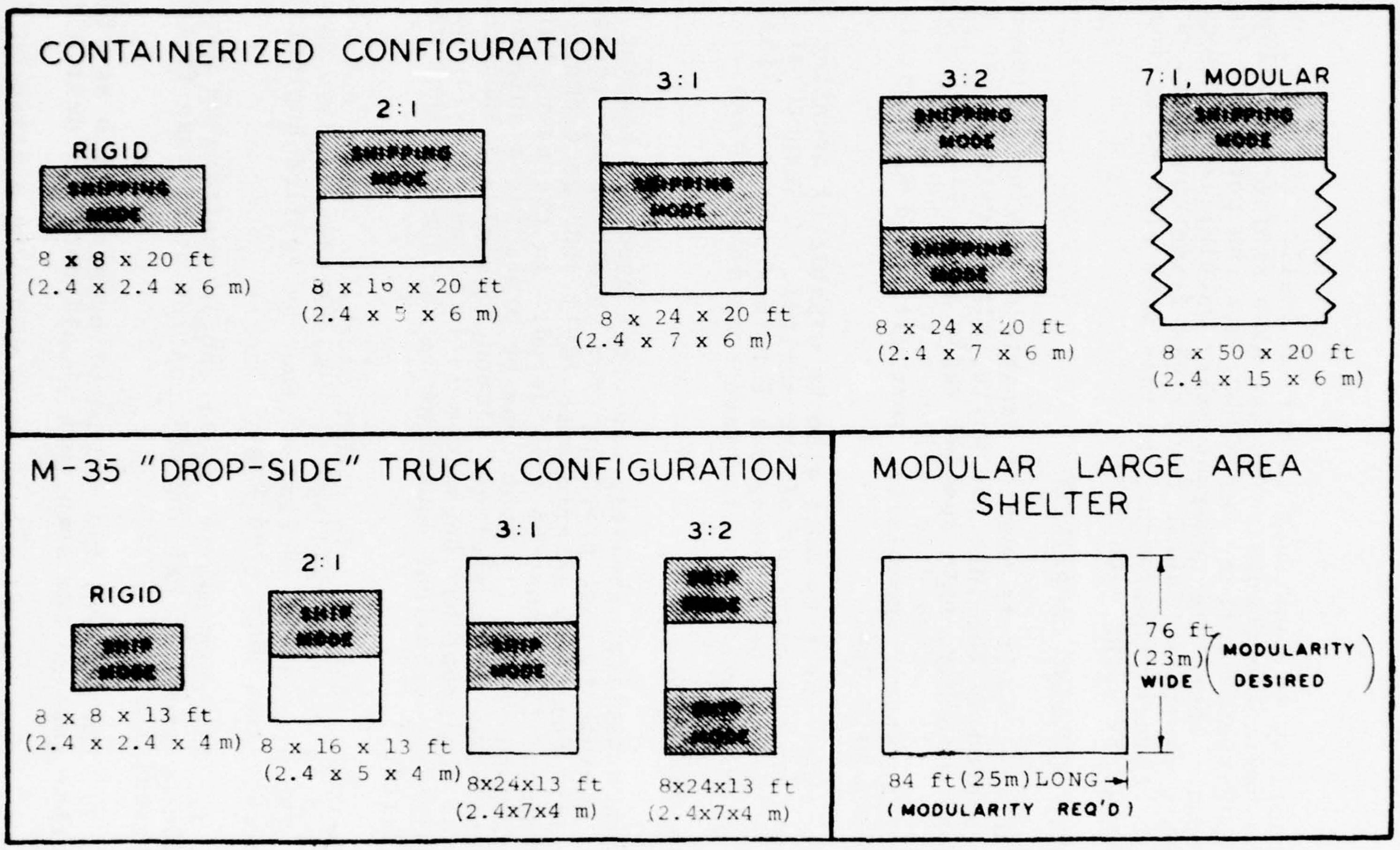

Figure 4. 1985 Shelter Size Requirements - Operational Mode

the capability to construct larger or smaller shelters, using the same basic components. The Loc Arch shelter, developed by Lockheed Marietta Company for AFCEC, has the potential for doing that. There are numerous other possibilities using air inflatable shelters, fabric over rigid frame concepts, or other designs. Future requirements in this area must be defined in more detail by using agencies.

EQUIPMENT MOUNTING CAPABILITY

Tactical shelters must be capable of having equipment racks mounted on the interior walls, either directly to the walls or, possibly, onto special racks which are connected to the walls. To accommodate various sizes of equipment racks, a "mount anywhere" capability, vertically and horizontally, must be somehow provided.

Tactical shelters must also be capable of mounting special equipment on the exterior of the shelter. A structural "add-on" kit may be advantageous for this purpose, although a kit of this type would also have some disadvantages.

RFI/EMI SHIELDING

Since tactical shelters are often used for housing electronic equipment, some provision for shielding the equipment from radio frequency interference (RFI) and electromagnetic interference (EMI) must be considered. In the past, this shielding has primarily been done by providing a shield around the periphery of the shelter, although shielding individual items of equipment has been done in some cases. Provision for shielding transient equipment in the shelter must also be considered.

Because shielding is rather expensive and is not always required, a form of "add-on" kit may be advantageous for this use. The previously-mentioned study by Applied Engineering Resources, Inc. suggested that:

1. Advanced family of air mobile shelters be designed to include no specific EMI and RFI control other than filters on electrical feed-throughs . . .

2. EMI control via sizing of openings such as windows and other gaps in the structure should not be a design goal . . .

3. EMI control should be provided by a strap-on flexible cover that has openings, if any, sized for particular bands of

wavelengths, and which surrounds the building, including the floor. 41

The RFI/EMI shielding problem is similar to the EMP problem mentioned in connection with nuclear protection, but at much lower magnitudes. Presumably, a design which solves the EMP problem would also solve the RFI/EMI problem.

DOORS, WINDOWS, AND OTHER OPENINGS

Another important mission-oriented consideration is the size and location of openings for windows, doors, and other purposes. Because of the RFI/EMI shielding problem, the need for a blackout capability, and other considerations in some shelters, permanent windows should be kept to a minimum. However, the need to provide openings in some shelters is evident. These openings could be provided by cutting openings in the standard shelter as necessary. At least one personnel door must be provided in each shelter. Another consideration is the need to get large equipment in and out of the shelter easily. The ability to remove completely at least one wall for this purpose would be highly desirable. Additional guidance from using agencies is needed.

RESPONSE

In some mission operations the time required to convert the shelter from transport mode to operational mode, or vice versa, is critical. In some existing systems, the time is less than 30 minutes, including all equipment adjustments. While some missions will always have more moderate response requirements, it is expected that even faster response will be required for some shelters in the future.

REUSE

The air transportability of shelters is expensive, as indicated by the fact that these shelters generally cost 3 to 10 times as much as equivalent conventional construction. Consequently, recoverability is generally advantageous. All shelters, therefore, should be designed for multiple reuse, unless an extremely inexpensive "throw away" shelter becomes available in the future.

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41. Bedford, Riley, and Jaffe, M., Air Mobility Shelter Concept Study, Technical Report AFCEC-TR-76-XX, (Tyndall AFB, Florida: September 1975), pp. 85-86.

MODULARITY

In order to provide maximum operational flexibility, the inherent ability to connect shelters together is desirable. If, for example, an 8 x 8 x 20 foot (2.4 x 2.4 x 6 m) expandable shelter could be connected to a non-expandable 8 x 8 x 20 foot (2.4 x 2.4 x 6 m) shelter, the need for a special 3:2 expandable shelter is eliminated. This feature could be provided rather easily if the removable side discussed under "Doors, Windows, and other Openings" is provided.

COMMONALITY

One of the primary objectives of the development of a new family of shelters must be to "assure a higher degree of commonality during production."[42] In future shelters the need for commonality will be amplified, because tooling for advanced materials requires a greater proportion of the total costs.[43] Consequently, replaceable panels of various kinds are envisioned.

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42. Malcolm R. Currie, Director of Defense Research and Engineering, Washington, D.C., memorandum to Assistant Secretary of the Army (R&D), 24 May 1974.

43. Bedford, Riley, and Jaffe, M., Air Mobility Shelter Concept Study, Technical Report AFCEC-TR-76-XX, (Tyndall AFB, Florida: September 1975), pp. 70-128.

SECTION VII

CONCLUSIONS

The future USAF requirements for air transportable shelters have been outlined, based on past history, recent developments, current DOD policy, apparent trends, and the predicted availability of new materials and processes. Specifically, shelter configuration requirements effected by transportation, worldwide climate extremes, the threat-imposed environment, and special mission considerations have been estimated. The major conclusions of this study are as follows:

1. The need for a family of air transportable shelters, with maximum commonality, to meet multiple mission requirements is evident. This family should be aimed for the time period 1985 and beyond.

2. The number of air transportable shelters used by the USAF will continue to increase. It is estimated that 3000 to 7500 shelters will be produced annually for the USAF in 1985, compared to the present rate of approximately 1500 annually.

3. Extensive use of commercial air transportable shelters for USAF requirements is not expected in the near future. However, increasing use of shelters developed by other U.S. and Allied Military services is expected.

4. Shelters configured in the shipping mode, like intermodal containers, are advantageous.

5. Two shipping configurations are needed: 8 x 8 x 20 foot (2.4 x 2.4 x 6 m) to meet ISO/ANSI standards and 8 x 8 x 13 foot (2.4 x 2.4 x 4 m) to meet truck transport requirements, assuming that "drop-side M-35 trucks will be used by the USAF instead of standard M-35 trucks for shelters.

6. Worldwide climate extremes have been determined, and are shown in Tables 7 and 8.

7. Protection against nuclear, conventional, chemical and biological threats would be expensive but appears to be needed. There are no existing criteria for providing protection from these threats. A technique of using special "add-on" protection and local materials has been suggested.

8. The primary sizes for future air transportable shelters should be as illustrated in Figure 4.

SECTION VIII

RECOMMENDATIONS

1. The USAF family of air transportable shelters should be developed in cooperation with the DOD-sponsored Joint Committee on Tactical Shelters (JOCOTAS) effort.

2. Criteria should be developed for air transportable shelters to provide protection from nuclear, conventional, chemical, and biological weapons. Use of local materials to provide part of this protection should be considered.

3. In addition to the "tactical shelters," a large, modular shelter should be developed as part of the family for aircraft maintenance, covered storage, and other large area functions. The characteristics of this shelter should be developed in a future study.

4. The advantages and disadvantages of special "add-on" kits to provide the following capabilities should be compared in a future study:

   a. Extreme climate capability.

   b. Combat protection--nuclear, conventional, chemical, and biological.

   c. Equipment mounting provisions.

   d. RFI/EMI shielding.

5. The DOD Joint Contingency Construction Requirements Study (JCCRS) should identify specific shelter requirements to be considered by JOCOTAS.

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APPENDIX A

DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING
WASHINGTON, D C 20301

24 MAY 1974

MEMORANDUM FOR THE ASSISTANT SECRETARY OF THE ARMY (R&D)

SUBJECT: Coordination of Development and Standardization of Shelters and Environmental Control Units

Over the past several years the Services have been developing systems that use shelters with environmental control and power units to provide a self-contained capability to operate in the field under all weather and climatic conditions. It is becoming increasingly apparent that the shelter and ancillary equipment area is rapidly growing into a major support function that requires closer coordination during the development phases of the systems involved in order to:

- Assure a higher degree of commonality during production.
- Achieve the necessary standardization for efficient sea, air and ground transportation.
- Save money by eliminating duplication and/or unnecessary development of new shelters and ancillary equipment.

My office has reviewed several of the research and development programs using these components and found that many projects are proposing to use shelters that will not be compatible with the International Standards Organization standards on shelter size, tie downs, etc. Also, duplication of development of shelters for electrical maintenance and other functions was indicated in some areas. In addition to these problems it was determined that there is no coordinated shelter and ancillary equipment program to meet survivability requirements such as those placed on the Joint Tactical Communications Office (TRI-TAC) TTC-39 switch.

In view of the fact that the Army is already responsible for mobile electric power units as the DOD Manager and for most shelters as the DOD Project Manager for Surface Container Systems, I would like you to conduct a review of shelter and environmental control equipment development now being conducted by the Services either as units by themselves or as part of a weapon/support system. The objective of this review will be to determine: (1) if there should be a DOD Program Manager to coordinate these developments and future standardization; (2) if the task should be assigned to an existing DOD Program Manager's office, or (3) if added emphasis should be given to the Defense Standardization Program in this area.

62612

I would appreciate a progress report on your action on 1 September 1974 and a final report on 1 December 1974. Copies of this memorandum are being provided to the Assistant Secretaries of the Navy and Air Force (R&D) so that they may assist your designated office in the performance of this task.

Malcolm R. Currie

cc: ASD(I&L)
ASN(R&D)
ASAF(R&D)
DTACCS

APPENDIX B

CHARTER FOR
JOINT COMMITTEE ON TACTICAL SHELTER (JOCOTAS)
17 April 1975

I. Purpose.

This Charter is to insure complete interservice awareness and coordination of the total Research, Development and Engineering (RD&E) Program for Department of Defense (DOD) Tactical Shelters. This Charter establishes:

a. Responsibilities for formulating and establishing policy and procedures for an integrated research, development and engineering program of Tactical Shelters to support military services and DOD components:

b. Procedures for the active participation of all military services and DOD components; and

c. Procedures to permit the timely introduction of new and improved Tactical Shelters.

II. Definition.

a. Tactical Shelter - A presized rigid/expandable, transportable structure designed to meet functional requirements by providing a live-in/work-in capability. (Specifically exempted - fabric wall shelters, air-supported structures, refrigerated shelters, modular or prefabricated structures designed to be shipped to the theater of operations and assembled with engineer unit support and containers).

b. Joint Committee on Tactical Shelter (JOCOTAS) - A Committee comprised of one voting member from each service.

c. Lead Service - The military service that has been assigned the responsibility to execute the RD&E Program formulated by the JOCOTAS and approved by Office of Secretary of Defense (OSD).

d. Engineering (Eng) - Includes the production engineering, standardization and specifications programs.

e. Research - Defense research is scientific study and experimentation directed toward increasing fundamental knowledge and understanding in the sciences. It also provides part of the base for subsequent exploratory, advanced and engineering developments in Defense-related technologies.

f. Development - This includes three categories; exploratory, advanced and engineering development, which contribute to:

(1) Significant improvements in or creation of useful products to meet specific performance requirements.

(2) Development of components for incorporation in end items to meet specific performance requirements.

(3) Construction of hardware for test purposes to determine feasibility of technical approaches.

g. Assignee Activity - The activity to which the responsibility for standardization of a Federal Supply Class (FSC) or Area has been delegated.

III. Scope and Authority.

A. Scope.

1. General:

This Charter applies to all DOD components engaged in supporting, or requiring Tactical Shelter research, development and engineering. It encompasses all tactical Shelter RD&E unless specifically exempted by the JOCOTAS and approved by OSD.

2. Specific:

a. JOCOTAS will consider all requirements for RD&E from all DOD military services and formulate these requirements into a Joint Tactical Shelter RD&E Program for submission as a Proposed DOD Program.

b. JOCOTAS shall establish policy and guidance for the development of the Tactical Shelter Program to enable the lead service, Army, to discharge its responsibilities.

c. Each service shall submit its own coordinated shelter development proposals to JOCOTAS for review and approval.

d. JOCOTAS shall develop a funded program following service priorities within programming and funding guidance by the Department of the Army (DA) for submission as a Proposed DOD Program.

e. The Lead Service, the U. S. Army, will execute the program recommended by the JOCOTAS and approved by OSD using the Command and administrative procedures of the U. S. Army Materiel Command (USAMC).

f. The Lead Service shall serve as the assignee and designate within its service an assignee activity for the FSC or group designated.

g. The Lead Service shall provide the Executive Secretary for the JOCOTAS.

B. Authority.

The voting representative of each service will have authority to make commitments.

IV. Organization and Operation.

A. Organization.

1. JOCOTAS Membership.

Each service (Army, Navy, Air Force and Marine Corps) will appoint a principal member, grade 06, GS-15 or below and, as a minimum, one alternate.

2. Chairmanship.

Chairmanship of the Committee shall be among the members of the committee and elected annually.

B. Operations - Operations shall be in accordance with the Joint Service Regulation for Tactical Shelters.

V. Meeting Agenda.

The Chairman will prepare the meeting agenda after soliciting items for discussion from each service. This will not preclude the Chairman from including items for discussion on his own initiative, as required.

Initially, the JOCOTAS will meet on a quarterly basis. The Chairman/members may propose adjustments to the frequency of meetings to facilitate workload and optimum phasing with the planning, programming and budgeting cycle.

VI. Meeting Records.

Minutes of each JOCOTAS meeting will be recorded and distributed by the Executive Secretary.

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APPENDIX C

INVENTORY TRANSPORT AIRCRAFT[a]

QUANTITY	DESIGNATION	MANUFACTURER
30	C-135	Boeing
9	VC-137	Boeing
1	VC-6A	Beech
3	C-131	Convair
21	C-9	Douglas
525	C-130	Lockheed
276	C-141	Lockheed
79	C-5	Lockheed

[a] Data from International Air Forces and Military Aircraft Directory.

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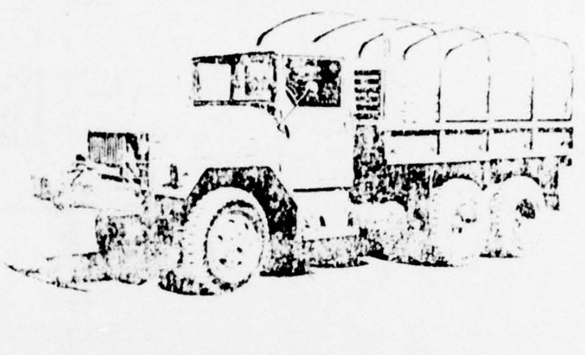
TRUCK, CARGO, $2\frac{1}{2}$ TON, 6X6, M35
154 IN. WHEELBASE, DUAL TIRES

APPENDIX D

M-35 TRUCK

SECTION: SQV-1
CODE: SQV-10
STATUS: STANDARD
DATE: 23 JANUARY 1959

CHARACTERISTIC SHEET **ORDNANCE TANK AUTOMOTIVE COMMAND**



DESIGNATIONS	VEHICLE DATA	
NOMENCLATURE	Truck, Cargo, $2\frac{1}{2}$ Ton, 6x6, M35	
MANUFACTURER	Reo Div. White Motor Co.	
MODEL	M35	
CHASSIS	M45	
CLASSIFICATION		
Designed for	Standard	
Air Transport Classification	Phase II	(Phase I
Bridge Classification	Class 20	Unladen)
PUBLICATIONS		
Technical Manuals	TM 9-8022 TM 9-8023-1, 2 & 3	
S N L	SNL G-742	
S C M		
FEDERAL STOCK NO.	2320-835-8464 W/WN. W/E.P.	
	2320-835-8463 W/E.P.	
CURB WEIGHT, FULLY EQUIPPED, LESS PAYLOAD AND PERSONNEL	W/Winch	WO/Winch
Front Axle	5810 lb.	5315
Rear Axle or Bogie	7070	7150
Total	12880	12465
PAYLOAD: Cross Country	5000 lb.	
Highway	10000	
GROSS WEIGHT, FULLY EQUIPPED, PLUS PAYLOAD AND PERSONNEL		
Front Axle	6256 lb.	5761
Rear Axle or Bogie	11974	12054
Total	18230*	17815*
TOWED LOAD ALLOWANCE		
Cross Country	6000 lb.	
Highway	10000	
SHIPPING DIMENSIONS		
Cu. Ft.	1224	1164
Sq. Ft.	184.3	175.3
LENGTH	$276\frac{1}{2}$	263
WIDTH	96 In.	
HEIGHT		
Overall Height	111 In.	
With Ring Mount	--	
Less Ring Mount	--	
Lowest Operable	79-11/16 In.	
CENTER OF GRAVITY LOCATION,		
At Curb Weight		
Above Ground	37-3/4 In.	37-1 In.
Rear of ℄ of Front Axle	77 In.	81 In.
With Payload w/o Crew		
Above Ground	48 In.**	48 In.**
Rear of ℄ of Front Axle	97 In.	100 In.

DESIGNATIONS	VEHICLE DATA	
PERFORMANCE	With	Less
For Gross Weight W/O Towed Load	Winch	Winch
Maximum Speed	58 MPH	
Maximum Grade		
Greatest Combined Reduction	63%	64%
Smallest Combined Reduction	3.6%	3.8%
Cruising Range		
For Gross Weight and Towed Load		
Maximum Speed	58 MPH	
Maximum Grade		
Greatest Combined reduction	46%	48%
Smallest Combined reduction	2.5%	2.5%
Cruising Range	Approx. 300 Miles	

Highway Travel At Indicated Gross Weight W/O Towed Load.

BODY

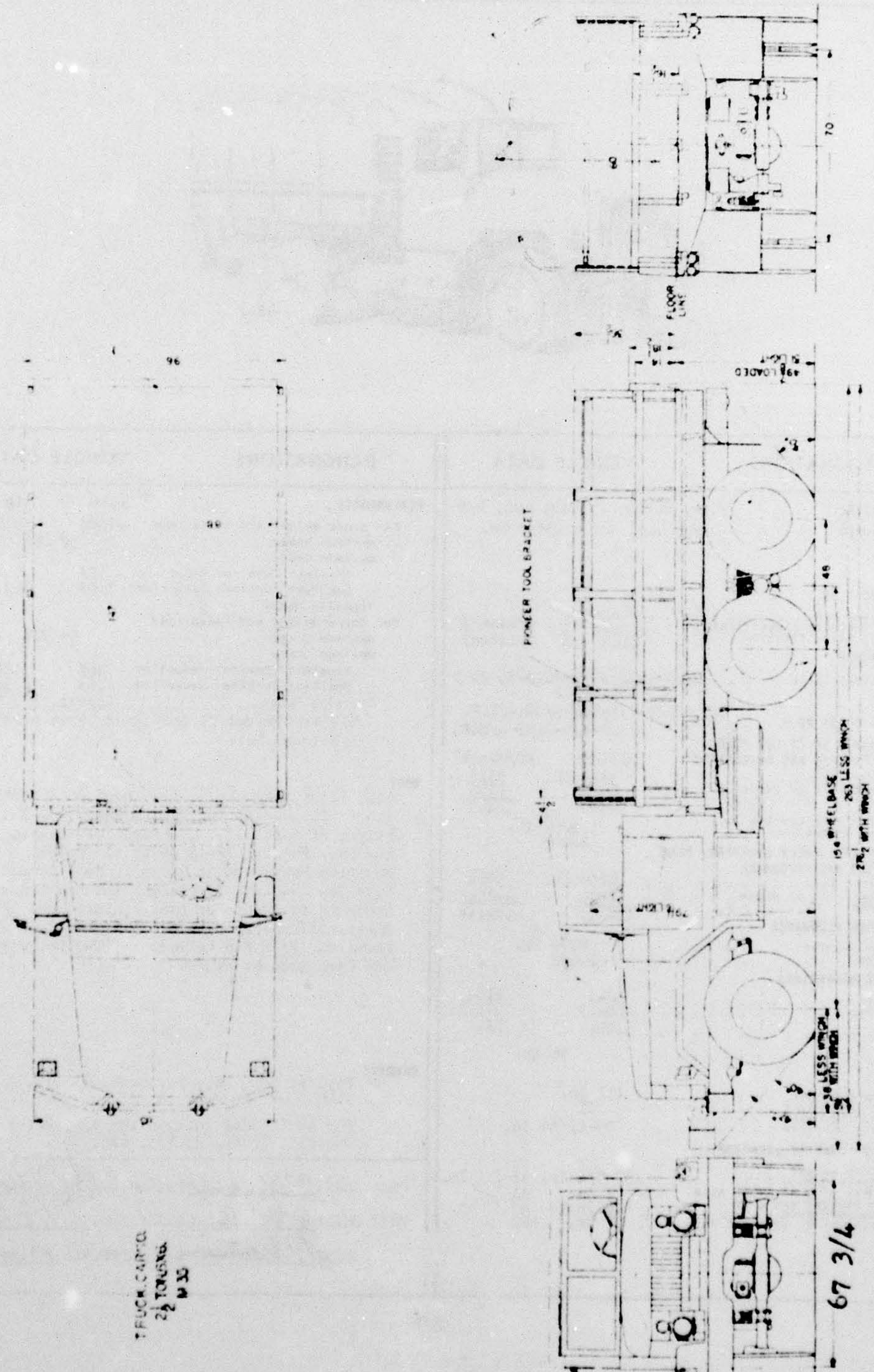
Flat Floor Cargo Body, All Steel Construction. Length Inside 147 In., Width Inside 88 In., Height of Sides 14 In., Height of Tailgate $16\frac{1}{2}$ In., Folding Troop Seats (In Folded Position Form Part of Racks). Body Includes Five Top Bow with Tarpaulins and End Flaps. Steps On Tailgate For Ease of Entrance. Four Amber Reflectors, Two On Front, One Each Side Forward. Four Red Reflectors, Two On Rear, One Each Side Rearward.

REMARKS

* Payload 5000 lb., Personnel 350 lb.
** With 5000 lb. Payload

For Additional Data On Vehicle, Refer To Chassis, Truck, $2\frac{1}{2}$ Ton, 6x6, M45.

PROJ. ENG. E C Blankenship BRANCH CHIEF R. A. Morrison
UNIT CHIEF R. A. Anderson CHIEF ENG. J B Hayes
SEC. CHIEF L P Martinson DATE APPROVAL 23 Jan 1959


TRUCK, CARGO 2½ TON 6x6 M35
PIONEER TOOL BRACKET
67 3/4
70
96
88
48

APPENDIX E

DISTRIBUTION OF ABSOLUTE MAXIMUM TEMPERATURES

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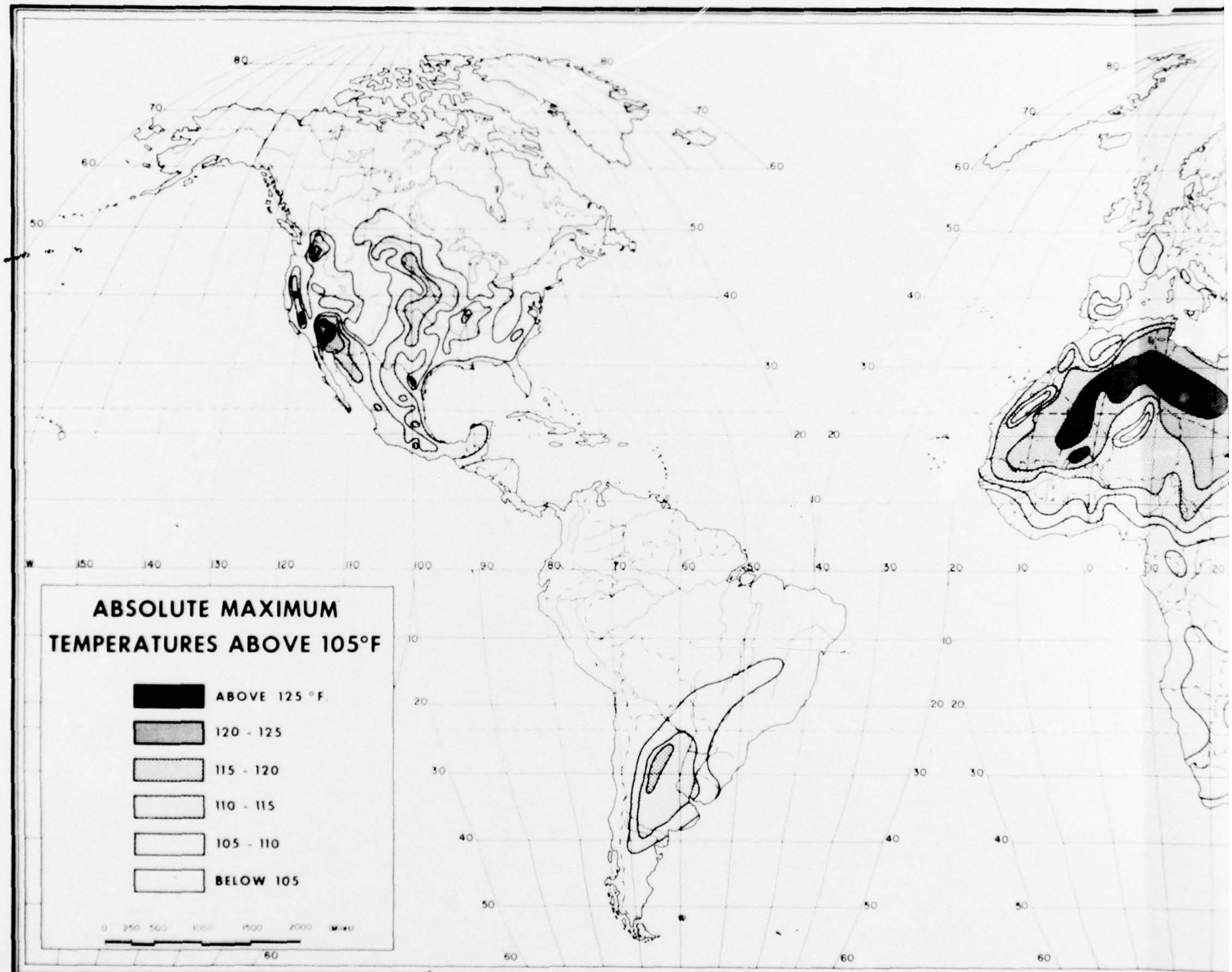
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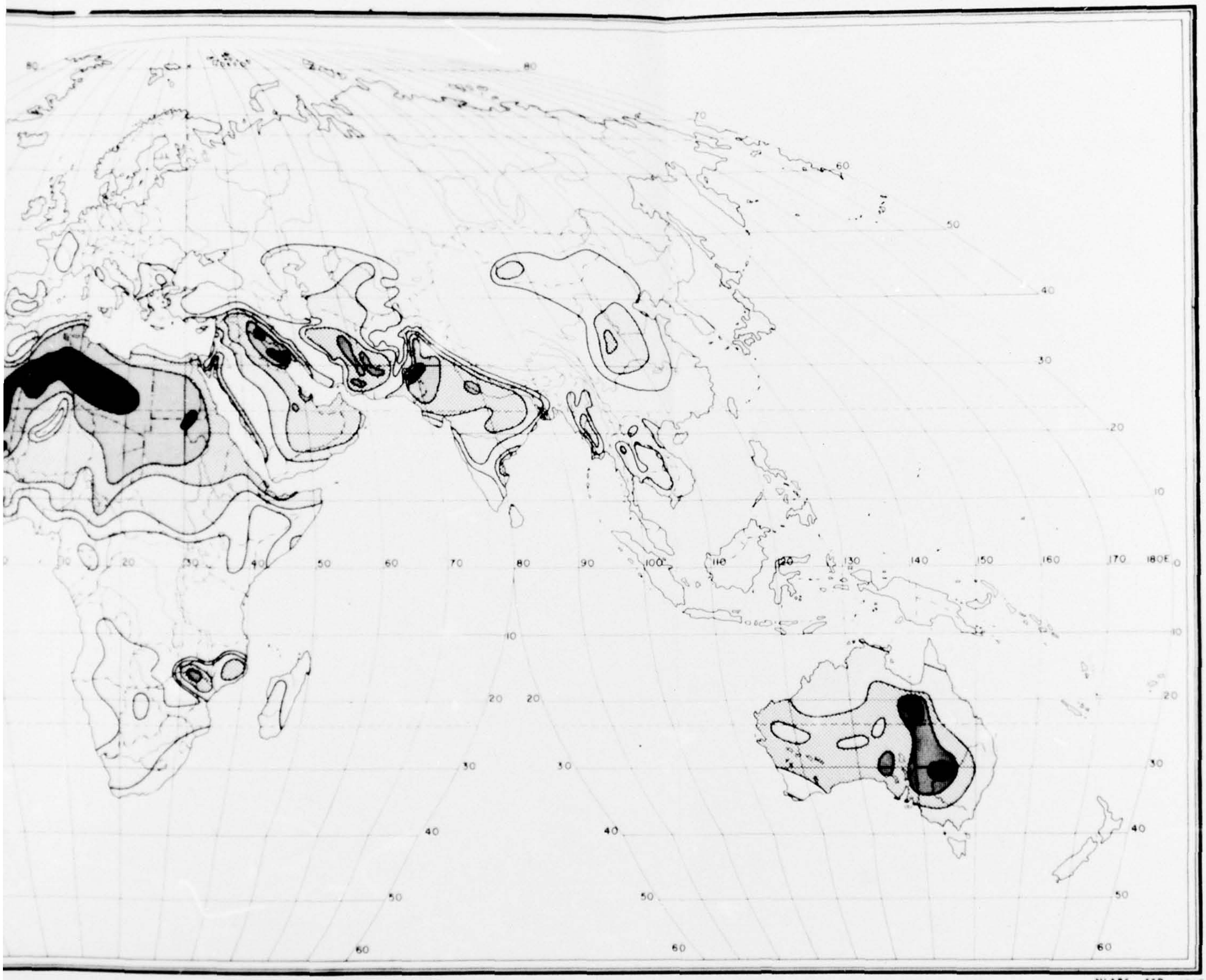
TEMPERATURES ABOVE 105°F
ABOVE 125 °F
120 - 125
115 - 120
110 - 115
105 - 110
BELOW 105



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APPENDIX F

DISTRIBUTION OF ABSOLUTE MINIMUM TEMPERATURES

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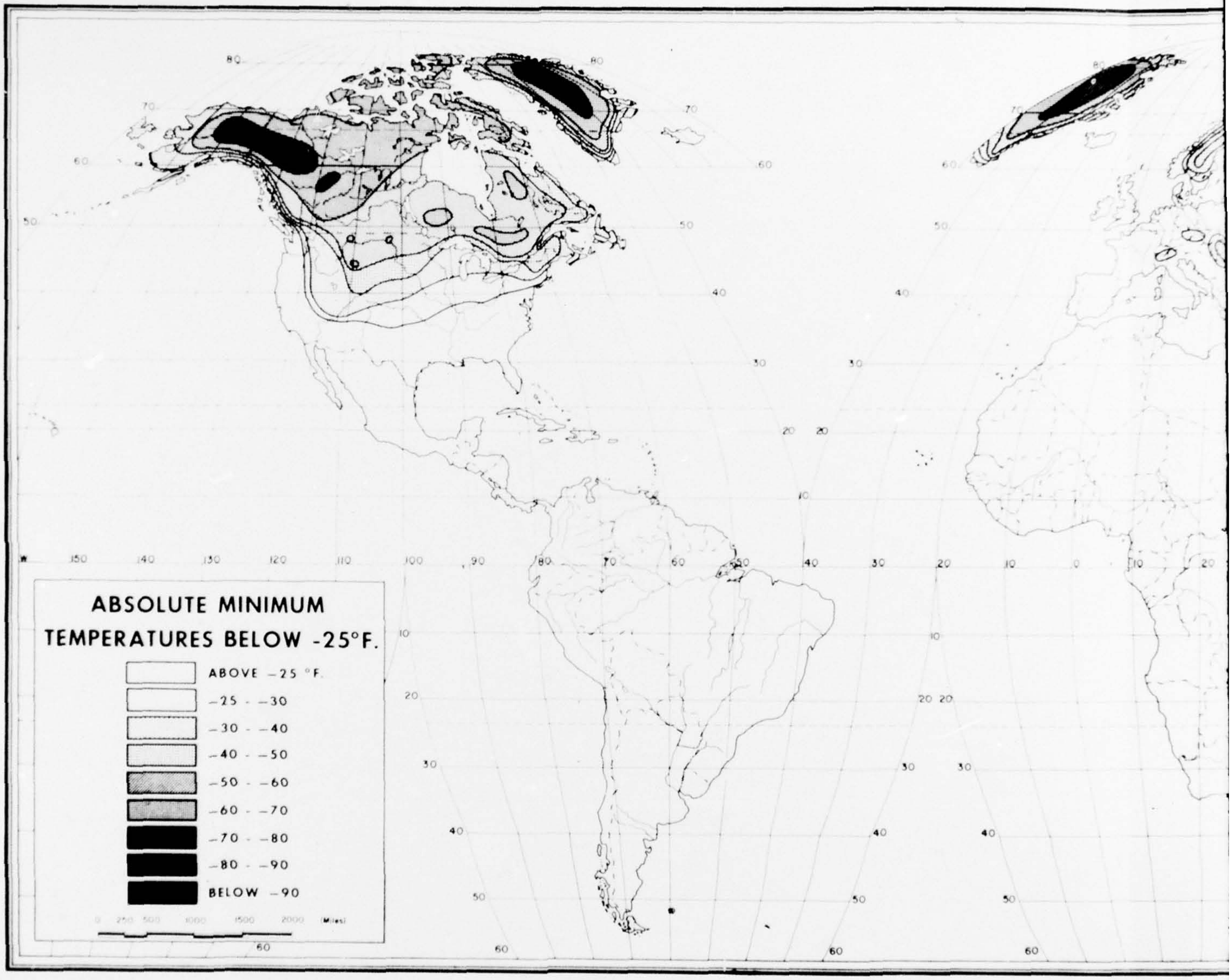
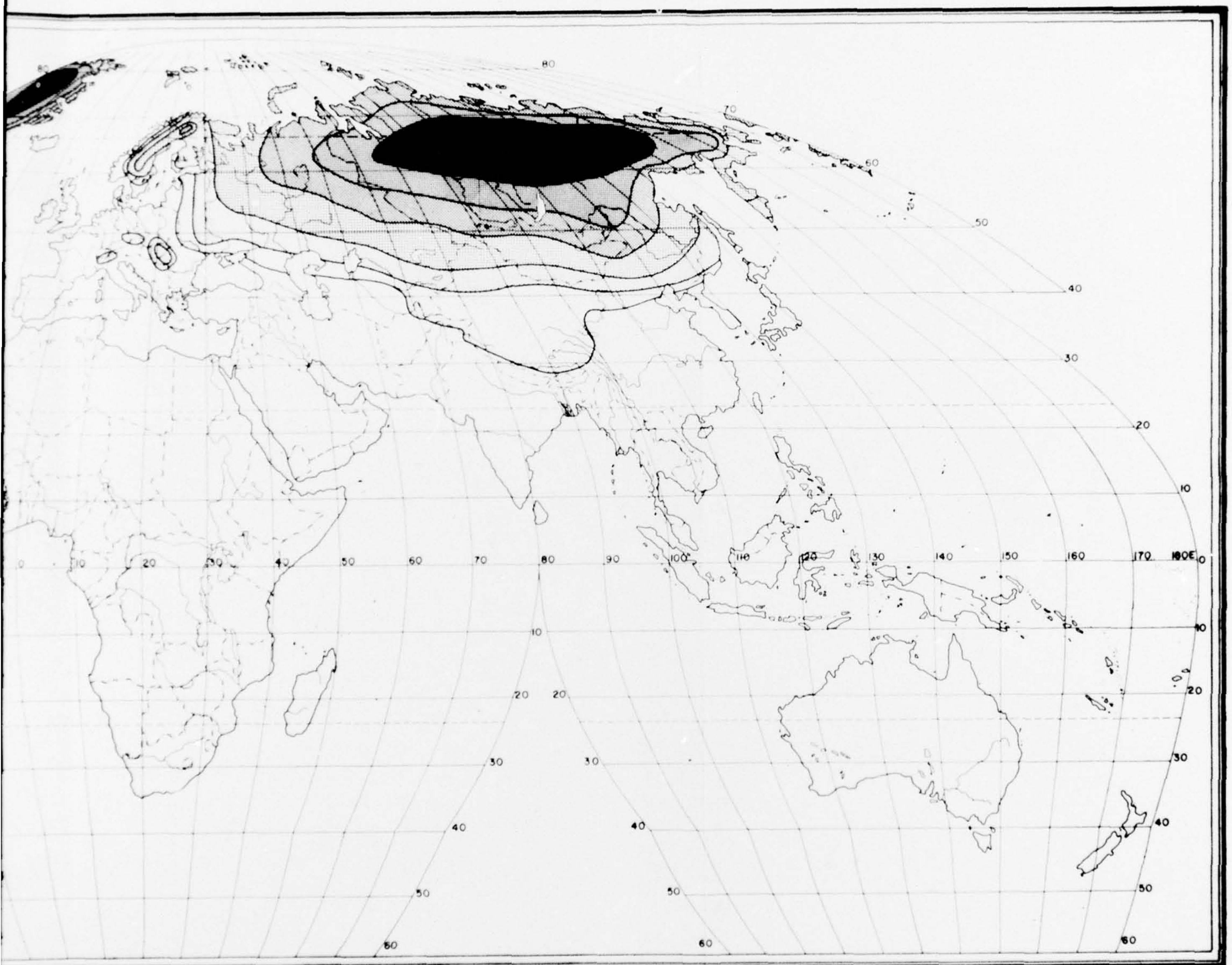

ABSOLUTE MINIMUM
TEMPERATURES BELOW -25°F.
ABOVE -25 °F.
-25 - -30
-30 - -40
-40 - -50
-50 - -60
-60 - -70
-70 - -80
-80 - -90
BELOW -90
0 250 500 1000 1500 2000 (Miles)



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INITIAL DISTRIBUTION

HQ USAF/PRE	1
HQ USAF/RDPQ	1
HQ USAF/PREC	1
HQ USAF/PREEO	1
Nav Facilities Engrg Comd/Code 03	1
Nav Const Battalion Ctr/Code 15	2
Nav Const Battalion Ctr/Civ Engrg Lab	1
HQ DA (DAEN-RDM)	1
USA MERADCOM	1
USA (CERL) DA Const Engrg Research Lab	1
HQ Marine Corps (Code LME)	1
DDC/TCA	12
ASD/DE	1
AUL (AUL-LSE-70-239)	1
AFSC/DE	1
AFSC/DL	1
M&SD/USMC Dev & Education Comd	1
AFATL/DLOSL	2
US Army Mobility Equip R&D Comd	1
US Army Cold Regions Research Engrg Lab	1
USAE Waterways Experiment Sta	1
US Army Natick Research and Dev Comd	1
MAC/DEMP	1
AFIT/DE	1
USAFSS/DEE	1
TAC/DE	1
ESD/DE	1
AFSC/SDA	1
AFCEC/SU	1
AFCEC/SUL	2
AFCEC/DE	1
AFCEC/DES	5

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